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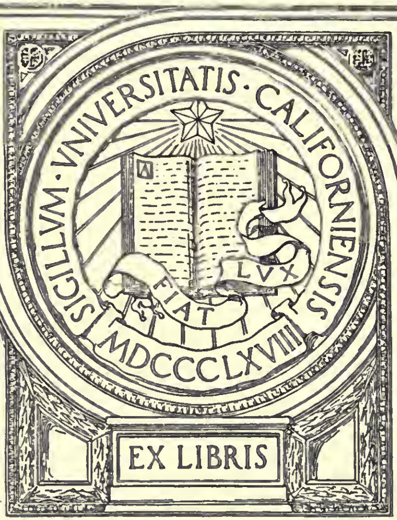

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AN INTRODUCTION

TO

GENERAL GEOGRAPHY

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AN INTRODUCTION
TO
GENERAL GEOGRAPHY

BY

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SOUTHERN BRANCH

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PREFACE

THIS little text-book deals with the general principles of geography more fully than is usual in the introductory chapters of the many excellent School Geographies of the World in common use, while at the same time it is less difficult to understand than the larger text-books dealing with various branches of the subject.

It consists of slightly expanded notes which have been used in class for several years, and have been found useful not only for revision, but also for reference to general principles while studying the geography of a special region.

It is hoped that the index is sufficiently full to serve the latter purpose.

The book is intended to be used by boys who not only work practical exercises, but also get full explanations from a teacher during oral lessons, and therefore I have not thought it either necessary or advisable to give a large number of illustrative examples in describing a phenomenon or to labour the explanation of a principle.

I have tried to condense the text as far as it could be done without sacrificing essentials, having in fact endeavoured to reduce it to a rather full note book of work done in class.

All the maps and diagrams have been drawn for this book with the same end in view. They are not intended to enable the reader to avoid using an atlas, but aim at directing his attention to the most important features found in larger maps.

A. A. G.

MARLBOROUGH.
December, 1914.

CONTENTS

CHAPTER I

THE EARTH A SPHERICAL BODY

Evidences of its shape, 1. The Earth an Oblate Spheroid, 3. Minor inequalities of surface, 4. Axis, 4. Equator, 5. Meridians, 5. Co-ordinates, 5. Latitude, 5. Parallels of Latitude, 6. Determination of Latitude, 7. Longitude, 8. Variation in length of a degree of Longitude, 9.

CHAPTER II

DAY AND NIGHT

Evidences for the rotation of the earth, 10. Time and Longitude, 11. Determination of Longitude, 12. Sundial, 13. Sidereal Day, 14. Solar Day, 15.

CHAPTER III

THE SEASONS

Constellations of the Zodiac, 16. Mid-summer in N. Hemisphere, Mid-winter in S. Hemisphere, 17. Winter in N. Hemisphere, Summer in S. Hemisphere, 22. Spring and Autumn, 23. Variation of length of Day and Night, 23. March of the Perpendicular mid-day rays of the Sun, 23. Tropics, 24. Arctic and Antarctic circles, 25. Zones, 25.

CHAPTER IV

CRUST OF THE EARTH

Cooling of the earth, 26. Configuration of earth and tetrahedral forms, 27. Distribution of Land and Water, 29. Chief facts concerning configuration, 31.

CHAPTER V

MAPS

Base Line, 32. Triangulation, 33. Map or Plan, 33. Scale, 33. Three classes of Maps, 34. Relief, 34. Position on the globe, 38. Projection, 40. Magnets, 49. Magnetic declination, 49. Magnetic inclination, 50.

CHAPTER VI

CLIMATE (TEMPERATURE)

Atmosphere, 52. Temperature of the atmosphere, 53. Isotherms, 55. Circumstances affecting Temperature, 56. July Isotherms, 62. January Isotherms, 65. Annual Range of Temperature, 67.

CHAPTER VII

CLIMATE (WINDS)

The Barometer, 70. Isobars, 71. Winds and pressure, 71. Convection currents, 71. Land and sea breezes, 72. Distribution of pressure, 75. Prevailing winds, 76. Anticyclones, 79. Cyclones, 79. Disturbances, 80. Distribution of pressure in July, 80. Distribution of pressure in January, 82. Monsoons, 83. Local winds, 84.

CHAPTER VIII

CLIMATE (RAINFALL)

Evaporation, 85. Condensation, 87. Clouds, Mist, Fog, 89. Dew, 89. Rainfall, 90. Distribution of Rainfall, 91.

CHAPTER IX

DISTRIBUTION OF VEGETATION

What plants need, 99. Chief types of vegetation, 102.

CHAPTER X

VEGETABLE PRODUCTIONS

Wheat, 109. Barley, 110. Oats, 110. Rye, 110. Maize or Indian Corn, 111. Rice, 111. Millet, 111. Vine, 112. Sugar-cane, 112. Sugar Beet, 113. Tea, 113. Coffee, 113. Cocoa, 113. Banana, 114. Date, 114. Sago, 114. Tapioca, 114. Arrowroot, 114. Potato, 114. Spices, 114. Opium, 115. Olive Oil, 115. Lemons and Oranges, 115. Cotton, 115. Flax, 116. Hemp, 116. Jute, 116, Caoutchouc and Rubber, 116. Tobacco, 116. Timber, 117.

CHAPTER XI

DISTRIBUTION OF ANIMALS

Habitat, 118. Range, 119. Origin of Species, 119. Dispersal, 119. Barriers, 120. Zoo-geographical Regions, 121. Domesticated animals, 122. Wild animals, 126.

CHAPTER XII

THE SEA

The Floor of the sea, 127. Sea water, 130. Temperature, 131. Currents, 131. Currents of inland seas, 134. Coral, 134. Tides, 135.

CHAPTER XIII

DISINTEGRATION OF THE CRUST OF THE EARTH

Crust of the earth, 144. Rocks, 144. Minerals, 144. Agents of disintegration, 144. Erosion, 147. Cañons, 147. Glens, 148. Wide river valleys, 150. Importance of rivers, 150.

CHAPTER XIV

DEPOSITION OF DETRITUS

Deposition in a river valley, 155. Formation of a Delta, 160. Marine Deposits, 161. Blown Sand, 163. Fossils, 163.

CHAPTER XV

SEDIMENTARY ROCKS

Consolidation of Deposits, 165. Some common Sedimentary Rocks, 165. Movements in the Earth's Crust, 168. Plane of marine Erosion, 168. Some commonly used terms, 169. Escarpment or Scarp, 170. Longitudinal and transverse valleys, 170.

CHAPTER XVI

IGNEOUS ROCKS

Evidences of Internal Heat of the Earth, 175. Volcanoes, 176. Plutonic Rocks, 177. Metamorphic Rocks, 178. Mountains, 178. Building Materials. etc., 180.

CHAPTER XVII

MINERALS

Faults in Rocks, 181. Minerals in Alluvium, 183. Mining Regions, 184. Some important Minerals, 184.

CHAPTER XVIII

COAL

Formation, 186. Mineral Oil (Petroleum), 187. Natural Gas, 187. Peat, 188. Industries on Coalfields, 188.

CHAPTER XIX

DENSITY OF POPULATION

Supply of Food, 189. Mineral or other wealth, 190. Intelligence of the People, 191. Health of a Region, 191.

CHAPTER XX

OCCUPATIONS

Hunting, 192. Fishing, 193. Pasturing, 193. Agriculture, 194. Lumbering, 195. Mining, 195. Manufactures, 196. Trade and Transport, 196.

CHAPTER XXI

TOWNS

Gates of Commerce, 203. Towns on Navigable Rivers, 204. Intersection of Trade Routes, 204. Mining Towns, 204. Manufacturing Towns, 205. Fortified Towns, 205. Religious Centres, 206. Health Resorts, 206.

CHAPTER XXII

RACES OF MANKIND

Origin of the Human Race, 207. Types of Man, 208.

CHAPTER XXIII

RELIGIONS

Development of Religions, 212. Heathenism, 213. Monotheism, 214.

CHAPTER XXIV

GOVERNMENTS

Origin, 215. Forms of Government, 216.

INDEX, 218.

CHAPTER I

THE EARTH A SPHERICAL BODY

Evidences of its Shape.

1. From any position on a plain or on the sea the view is bounded by a line where the earth appears to meet the sky. This line is called the sensible horizon. The three important facts concerning the sensible horizon are the following:—

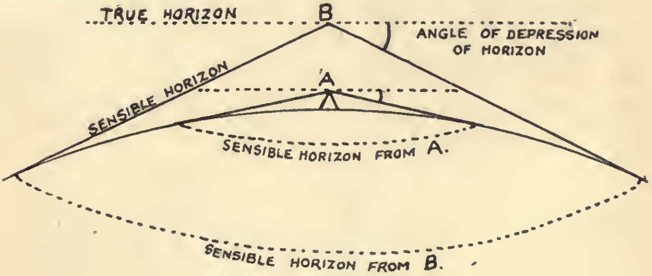


Fig. 1.

(*a*) It is always circular in form.

(*b*) Its extent increases with increasing elevation.

(*c*) The higher we ascend the greater becomes the angle of depression between the sensible horizon and the true horizontal plane through the eye (Fig. 1).

The above can be true only if the earth is spherical. If the earth were flat the sensible horizon would coincide with the true horizon for all altitudes.

2. When we observe an incoming vessel we first see the top of the mast above the horizon. Then the lower parts gradually come in sight, the hull being the last to appear. Again, while only the top of the mast is visible from the shore, the whole vessel may be seen from the top of the cliff (Fig. 2).

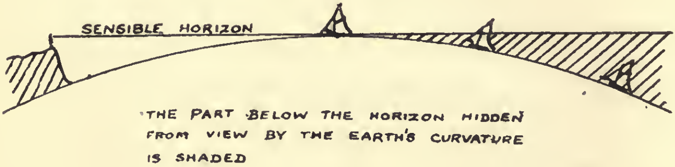

SENSIBLE HORIZON
THE PART BELOW THE HORIZON HIDDEN FROM VIEW BY THE EARTH'S CURVATURE IS SHADED

Fig. 2.

3. Three upright rods A, B, and C are stood at equal heights above a level sheet of water in a straight line so that A and C are one mile apart. On looking through a telescope so that the tops of A and C are in the same straight line, it is found that the top of B is eight inches above that level. This shows that the surface of the water must be convex (Fig. 3).

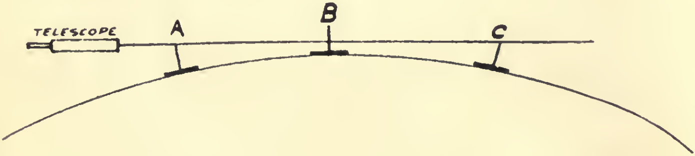


Fig. 3.

4. The earth has been circumnavigated and everywhere the above evidences hold good.

5. During an eclipse of the moon the shadow of the earth falls on the moon and it is seen that the edge of the shadow is always part of a circle (Fig. 4).

6. The earth is one of a number of planets and as all the others are spherical there is good reason to suppose the earth is no exception.

7. The sun rises earlier for places east and later for places west of any locality. If the earth were flat the sun would rise at the same moment at all places.

8. The Pole Star is seen on the horizon when observed from the equator. As the observer goes north the Pole Star is seen to rise above the horizon one degree for every 69 miles until at the North Pole it is overhead.

It must be noted that the Pole Star is not exactly at the pole of the heavens but describes a small circle around it during a sidereal day.

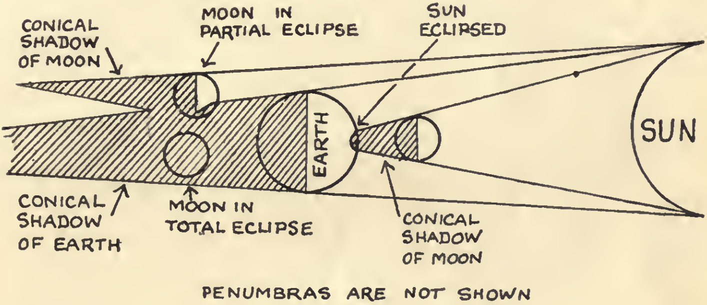


Fig. 4.

The Earth an Oblate Spheroid. Accurate measurements of the amount of curvature at different places on the earth's surface show that the length of a degree of latitude is greatest nearest the poles and least nearest the equator; or, to put it in another way, a degree of latitude nearer the pole is part of a larger circle than a degree of latitude nearer the equator (Fig. 5).

The equatorial diameter is 7926·6 miles while the polar diameter is 7899·6 miles. The poles are therefore 13½ miles nearer the centre of the earth than is the equator.

Such a sphere flattened at the poles is termed an oblate spheroid.

Minor inequalities of Surface. The highest mountain is about 5 miles high and the deepest trough in the ocean is about 6 miles deep: that is the greatest difference is about 11 miles. This is less than $\frac{1}{400}$ of the earth's radius so that on a globe 8 feet in diameter this difference would be represented by about $\frac{1}{10}$ of an inch.

Consequently the minor inequalities do not interfere with the general shape of the earth but cause merely a relatively slight roughness.

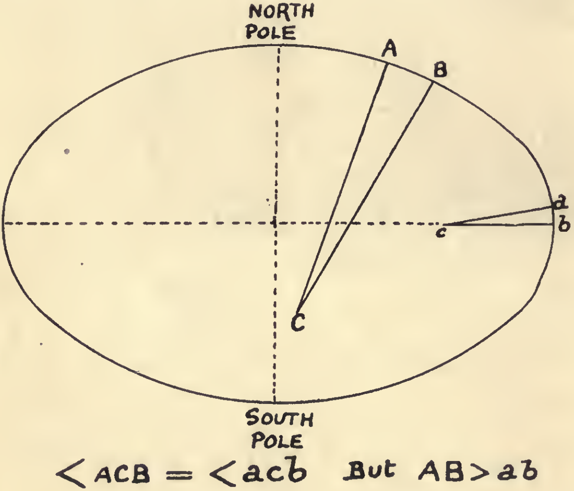


Fig. 5.

Axis. All the heavenly bodies appear to revolve around the earth, rising in the east and setting in the west. The circles they describe around the heavens are concentric. Their common centre is called the celestial pole.

The stars retain their positions relative to one another year after year but the nearer bodies, the sun and planets, have more complicated apparent motions.

The apparent daily revolution of all the heavenly bodies is best accounted for by supposing that the earth rotates every 24 hours. The imaginary line about which it rotates is termed its axis.

The axis always retains very nearly the same direction so that at any moment in the year it points in a northern direction towards the north celestial pole, while in a southern direction it points to the south celestial pole, a point in the southern sky exactly 180 degrees from the north celestial pole.

Equator. When a sphere is cut by a plane, the section is always a circle. If the plane passes through the centre of the sphere, the circle is the largest possible and is termed a great circle. If the plane of section is at right angles to the axis and midway between the poles, the great circle thus produced is called the Equator.

The equator may also be described as a great circle drawn round the globe midway between the poles.

Meridians. Seeing that there are an infinite number of directions which a plane may take in passing through the centre of a sphere, it is clear that an infinite number of great circles may be drawn on the globe. At present only those passing through the poles concern us. These, or more strictly, their halves, are called meridians. A meridian can therefore be defined as a semicircle terminated by the two poles. It is termed "meridian" because all points on it have midday at the same moment.

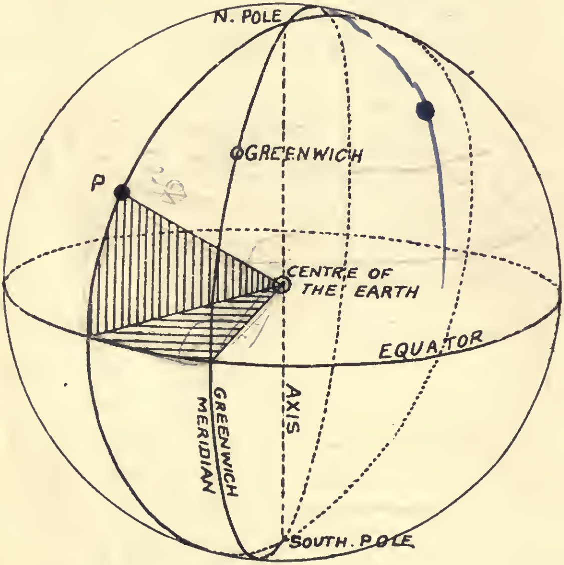
Co-ordinates. To indicate the position of any point on the globe it is necessary to have two reference lines or axes. These are settled in an arbitrary manner.

The Equator is taken as one reference line.

The Meridian passing through Greenwich is most generally adopted as the other.

Latitude. Latitude is the distance north or south of the equator. It is measured in degrees. Each degree is subdivided into 60 minutes and each minute is subdivided into 60 seconds. The conventional signs °, ′, ″ are used to denote degrees, minutes, and seconds, respectively. Thus 8 degrees 16 minutes 40 seconds is written 8° 16′ 40″.

If the latitude of a point *P* is required, we find the meridian passing through *P* (Fig. 6). It is then quite clear that the angle subtended at the centre of the sphere by the arc of the meridian between the equator and the point *P* will give us the latitude of that point.



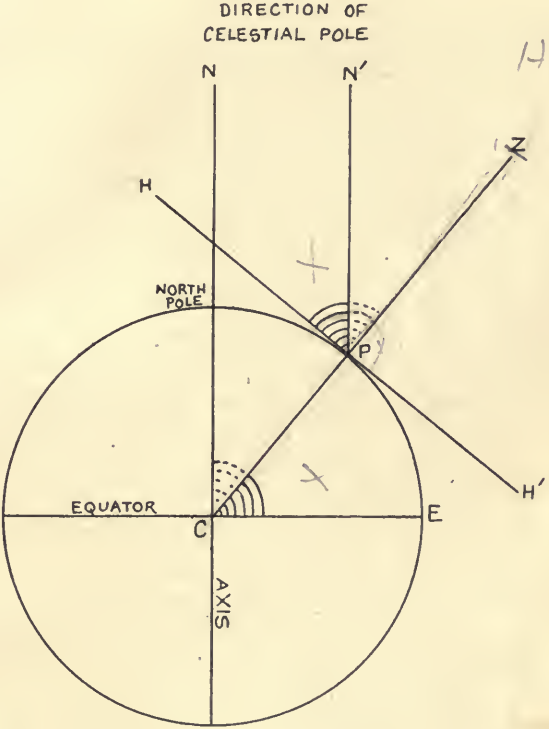
VERTICALLY SHADED ANGLE GIVES THE LATITUDE OF P.
HORIZONTALLY " " " " LONGITUDE " "

Fig. 6.

It is also evident that the latitudes of the north pole and the south pole will be 90° N. and 90° S. respectively.

Parallels of Latitude. If any circle is drawn round the earth parallel to the equator, all points on that circle will have the same latitude. On maps such parallels are drawn at convenient distances of one, ten, or more degrees according to the scale of the map.

Determination of Latitude. As the Pole Star is at an enormous distance from the earth, all rays of light reaching the earth from it can be considered to be parallel.



HPH′ = E

Fig. 7.

Now in any position P (Fig. 7) PZ, which is CP produced, will be the vertical, and HPH' a plane tangential to the sphere will be the horizon. If PN' is the direction of the pole star then :—

$$Z\hat{P}N' = Z\hat{C}N.$$

But $$Z\hat{P}H = E\hat{C}N \text{ (Rt } \angle \text{s)},$$

$$\therefore \quad H\hat{P}N' = E\hat{C}P.$$

But $E\hat{C}P$ is the angular distance of P north of the equator. Therefore $E\hat{C}P$ will be the latitude of P.

It follows that the angular distance of the Celestial Pole above the horizon will give us the latitude at the point of observation. At the North Pole the Celestial Pole will be in the zenith, i.e. at the point exactly overhead. At the equator it will be on the northern horizon.

Consequently, to determine latitude by this method, the altitude of the Celestial Pole must be found.

This can be found by using a Theodolite to find the altitude of a star as it crosses the meridian. The angular distance between the star and the Celestial Pole can be found by reference to astronomical tables, and hence the elevation of the Celestial Pole above the true horizon can be calculated and the latitude of the point of observation found.

The sextant is employed on a vessel where the ship's motion prevents the use of a Theodolite. The greatest altitude of the sun (occurring at noon, local time) may be observed. The exact position of the sun among the stars on any day can be found from astronomical tables, and hence the altitude of the Celestial Pole can be calculated. This is the method usually adopted on board ship and in an unsettled region.

Longitude. Longitude is the angular distance east or west of the Greenwich meridian.

The longitude of the place P is measured by first finding the meridian which passes through P. Then the angle subtended at the earth's centre by the arc of the equator between that meridian and the Greenwich meridian will give the longitude.

It is evident that Long. 180° W. is also Long. 180° E.

Determination of Longitude (see under **Day and Night**).

Variation in length of a Degree of Longitude. Suppose two meridians are drawn one degree apart. They meet at the poles where 1° Long. will have no length at all. At the equator they will be approximately 69 miles apart. Sixty-nine miles will therefore be the length of one degree of longitude at the equator. The further from the equator the shorter will be a degree of longitude until at the poles it will vanish.

We have seen that one degree of latitude varies only to a slight extent, becoming slightly longer the nearer we approach the poles. Consequently in putting an approximate scale of miles on a map one degree of latitude can be taken as 69 miles.

CHAPTER II

DAY AND NIGHT

It is evident that one half of the earth will be in sunlight and the other half in darkness (neglecting the effect of twilight and of refraction on the apparent position of the sun).

First, imagine the Greenwich meridian to be opposite the source of light, then, supposing the earth's axis to be perpendicular to the plane of the earth's orbit, it is clear that every point on the meridian will be equidistant from the east and west edges of the shaded side. This represents the noon position for all points on that meridian.

It can be seen that the same holds good with respect to every other meridian as it is brought opposite the sun. Thus a meridian is a line joining all points which have midday at the same moment.

Now imagine the axis to be inclined so that one of the poles is in the light half and the other in the dark half. The above facts still hold good, but we notice—

(1) A certain part of the meridian will be in darkness at midday.

(2) A certain part of the other half of the great circle which is in the midnight position will be in the light half of the globe.

Evidences for the Rotation of the Earth.

1. If a stone is dropped into a deep well, it always knocks against the eastern side of the well. Similarly a stone dropped from a tower falls a little to the east of the point immediately underneath. This can be explained by supposing that the earth rotates from west to east; in which case, the velocity of the top of the tower will be greater than the velocity of its base.

2. Foucault's Pendulum. A very long heavy pendulum carefully set swinging in a vertical plane so that it traces a straight line over the floor does not continually swing over the same line. The line traced out moves through an angle in a clockwise manner. Now it is known that the pendulum will continue to swing in the same plane in space. Therefore we conclude that the floor is moving in a counter-clockwise manner which will be the case if the earth rotates from west to east. This difficult experiment was performed by Foucault in the Pantheon.

3. Foucault obtained a very similar result by using a gyroscope.

4. The alternation of day and night can be most easily explained if the earth rotates.

5. It is more reasonable to suppose that the earth

rotates and causes the apparent daily revolution of the celestial bodies than to suppose that all the celestial bodies revolve around the earth.

6. Ferrel's Law, which states that in the Northern Hemisphere winds are deflected clockwise and in the Southern Hemisphere counter-clockwise, can be readily explained if the rotation of the earth is assumed.

7. The general tendency of the tidal wave to sweep around the earth from east to west is accounted for on the assumption that the earth rotates from west to east.

8. The spheroidal form of the earth is what might be expected if the body rotated while in a fluid state.

9. The phenomenon termed "aberration of light" is due to the fact that light travels with a finite speed while the observer is also moved by the earth's rotation. This alters the apparent direction of a heavenly body in the same way that the earth's rotation, or the movement of a vessel or a train, alters the apparent direction of a wind. This aberration can be explained if the earth rotates.

Time and Longitude. Assuming the rotation of the earth from west to east it is evident that when it is noon at Greenwich it will be A.M. on any meridian west of Greenwich and P.M. on any meridian east of Greenwich. Similarly for the noon position of any other meridian.

Moreover, when any meridian is in the noon position the other half of the circle of which the meridian is a part is in the midnight position.

The "Date Line" does not coincide with the 180° meridian throughout its entire length but follows a zig-zag course among the islands near that meridian.

Each meridian makes a complete journey in 24 hours. Therefore it travels over one degree in $\frac{24 \times 60}{360}$ minutes, i.e. 4 minutes.

Thus at all points on the meridian 1° E. of Greenwich the local time will be 4 minutes later than the Greenwich time at the same moment.

At all points on the meridian 1° W. of Greenwich the local time will be 4 minutes earlier than the Greenwich time at the same moment.

It must be clearly understood that latitude has nothing whatever to do with time.

Determination of Longitude. The aim is to find the difference between local time and Greenwich time. Greenwich time may be found in several ways:—

1. A chronometer set by Greenwich time may be carried by the traveller. This is the method employed by navigators and by travellers in unsettled regions.

It is only approximately accurate, for the best chronometer cannot be relied upon to give accurate Greenwich time.

2. Where the telegraph is available, time signals can be sent. The extension of the use of wireless telegraphy will enable much greater use to be made of this method of obtaining accurate Greenwich time.

3. The time of occultation of stars, being accurately known and given in astronomical tables, is another means of obtaining Greenwich time.

It is also necessary to obtain local time. This can be obtained with great accuracy by observing the instant of transit of a known star across the meridian. As the position of the sun among the stars at any time is given in astronomical tables, local time can readily be calculated. These observations are impossible in the case of a moving vessel, neither can travellers crossing unsettled regions make use of such observations, so that in these circumstances local time is found by observations of the sun. The altitude of the sun is observed, say, by a sextant on board ship, when the sun is at a distance from the meridian.

If the latitude is known, then the angular distance of the sun from the meridian can be calculated, and in this way local time is found.

Suppose that at a point P it is noon (local time) at the same moment when it is 3 P.M. at Greenwich. Clearly the longitude of the place is $\frac{3 \times 60}{4}$ degrees, i.e. 45 degrees. And as the local time is earlier than Greenwich time at the same moment the point P must be west of Greenwich. Therefore the longitude of P is 40° W.

Sundial. A simple form of sundial is a rod, fixed in a direction parallel to the earth's axis, casting a shadow on a horizontal surface. The principal facts to notice are the following:—

1. As the sun crosses the heavens from E. to W., the shadow of the rod will move from W. to E. on the northern side of the rod (if the sundial is north of the equator).

2. The length of the shadow is greatest at sunrise and sunset and least at midday.

(At the equator the rod would be horizontal and the length of its shadow would not vary.)

3. The midday shadow is longest at mid-winter and shortest at mid-summer.

4. The shadow at 6 A.M. will run due west from the base of the rod.

5. The shadow at 6 P.M. will run due east from the base of the rod.

(At the equator a horizontal dial would be of little use, because the shadows cast in the early and late hours of the day would need a dial having a ridiculously great E. and W. extension while the shadows cast at 6 A.M. and 6 P.M. would be off the dial, no matter how wide it were made. Obviously a vertical dial is more suitable in low latitudes.)

6. Lines can be drawn at hourly or other intervals. These radiate from the base of the rod. At the Poles

these angles would be equal. At the equator the lines would be parallel but not equally distant. At intermediate latitudes the angles would be unequal.

The important fact to remember is that the sundial indicates true local solar time.

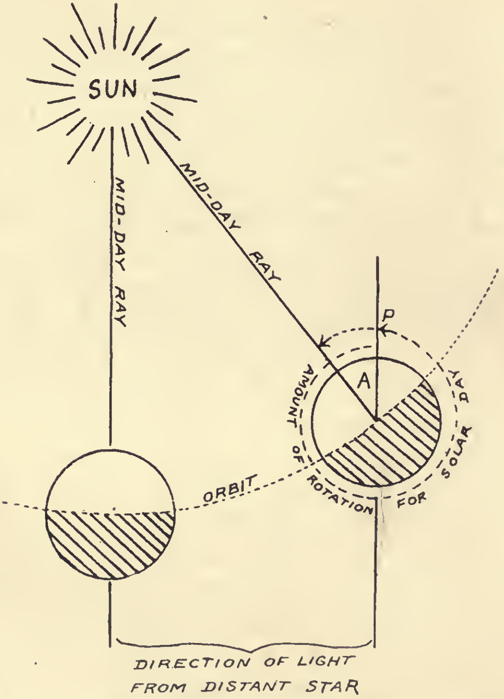

SUN
MID-DAY RAY
MID-DAY RAY
P
A
AMOUNT OF ROTATION FOR SOLAR DAY
ORBIT
DIRECTION OF LIGHT FROM DISTANT STAR

Fig. 8. Angle *A* shows additional amount of rotation beyond 360° during the solar day. The sidereal day would end at *P*. [The displacement of the earth along its orbit is greatly exaggerated.]

Sidereal Day. The time taken for the earth to rotate on its axis can be measured by the time of apparent revolution of any star. A transit instrument is used for this purpose. From the moment a star crosses the wire to the moment when it crosses the wire on the next night is the period taken for the earth to rotate. This time is the length of a sidereal day. It is approximately invariable.

Solar Day. (Fig. 8.) If the period from the moment the sun is due south on one day to the moment when it is due south the next day is measured, it is found to be longer than the sidereal day. This is explained by the fact that the revolution of the earth round the sun causes it to be carried to a new position during its own rotation so that it has to rotate through more than 360° to bring the sun to the same meridian on the next day. Moreover the solar day is variable in length, for the earth does not travel along its orbit at a uniform rate, its rate being fastest at the end of December and slowest at the end of June.

In measuring time by clocks, the Mean Solar Day is found by taking the average of the 365 solar days. Thus one hour of clock time is $\frac{1}{24}$ of the length of a mean solar day. The mean solar day is very nearly 4 mins. longer than the sidereal day.

CHAPTER III

THE SEASONS

FOUR facts have to be taken into account in understanding how the seasons are caused :—

1. Rotation of the earth on its axis.

2. Revolution of the earth around the sun.

3. The earth's axis is inclined to the plane of its orbit at an angle of 66½°. Or, put in another way, the plane of the earth's equator is inclined to that of the earth's orbit at an angle of 23½°.

4. The direction in which the earth's axis points is nearly constant. The prolongation of the axis would pass

through very nearly the same point in the heavens at any moment in the year.

Constellations of the Zodiac. As the earth revolves around the sun it is evident that the sun appears to traverse a particular path among the stars. This fact is one of the best evidences of the revolution of the earth.

The following is a list of the constellations of the zodiac through which the sun passes during its apparent annual journey among the stars.

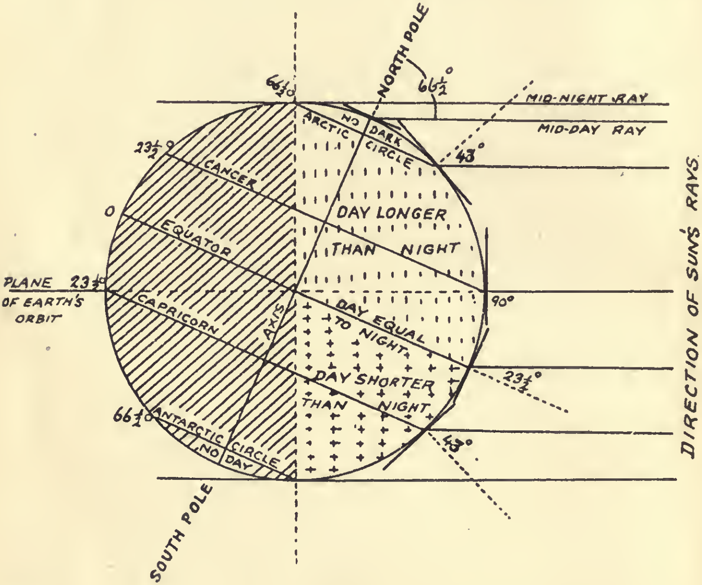


Fig. 9.

The Ram, the Bull, the Heavenly Twins:
And, next the Crab, the Lion shines,
The Virgin, and the Scales.
The Scorpion, Archer, and the Goat,
The man who carries the watering pot,
(Aquarius) and Whales.

Mid-summer in N. Hemisphere: Mid-winter in S. Hemisphere. (Fig. 9.) This state of affairs occurs on or near June 21st, when the sun appears to be situated in the constellation known as Cancer (the Crab). At that moment the North Pole is turned towards the sun to such an extent that:—

1. All the land within the circle 66½° N. Lat. is in the illuminated half of the globe. Here the day is 24 hours long.

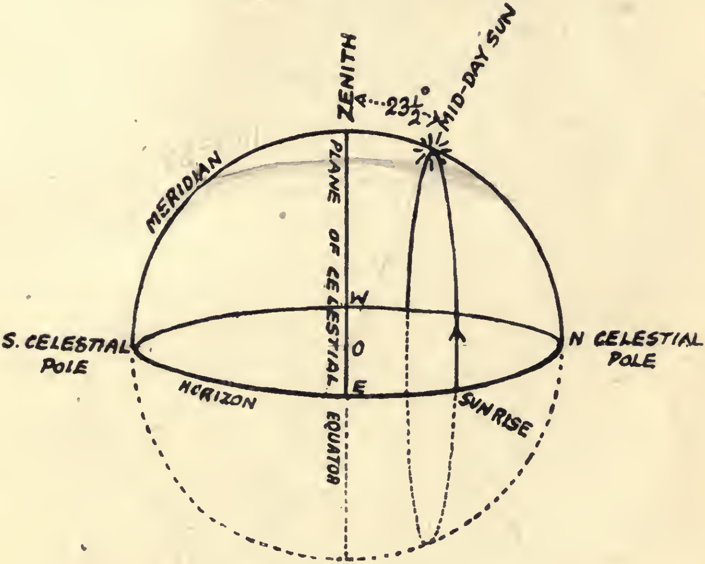


Fig. 10. *O*, point of observation.

2. All the land within the circle 66½° S. Lat. is in the dark half of the globe. Here the night is 24 hours long.

3. At the equator the day will last 12 hours and the night 12 hours while the path of the sun across the heavens will be 23½° N. of the zenith. (Note that in all cases the sun's daily path is parallel to the Celestial Equator.) (Fig. 10.)

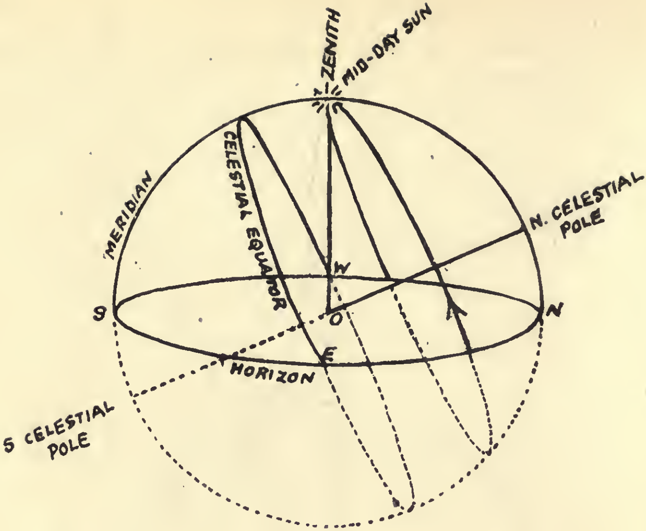

ZENITH
MID-DAY SUN
MERIDIAN
CELESTIAL EQUATOR
N. CELESTIAL POLE
W
S
O
N
E
HORIZON
S CELESTIAL POLE

Fig. 11.

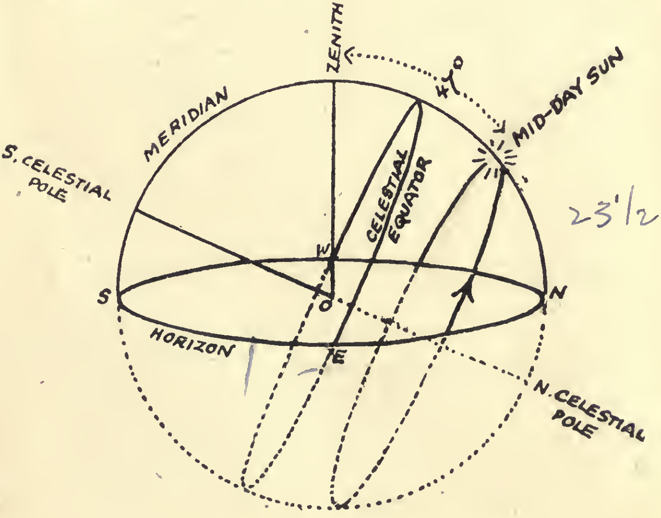

ZENITH
47°
MID-DAY SUN
MERIDIAN
S. CELESTIAL POLE
CELESTIAL EQUATOR
23½
W
S
O
N
HORIZON
E
N. CELESTIAL POLE

Fig. 12.

4. At every point on Lat. 23½° N. the sun will be in the zenith at midday. The day will be longer than the night. (Fig. 11.)

5. At every point on Lat. 23½° S. the sun will be 47° N. of the zenith at noon. The night will be longer than the day. (Fig. 12.)

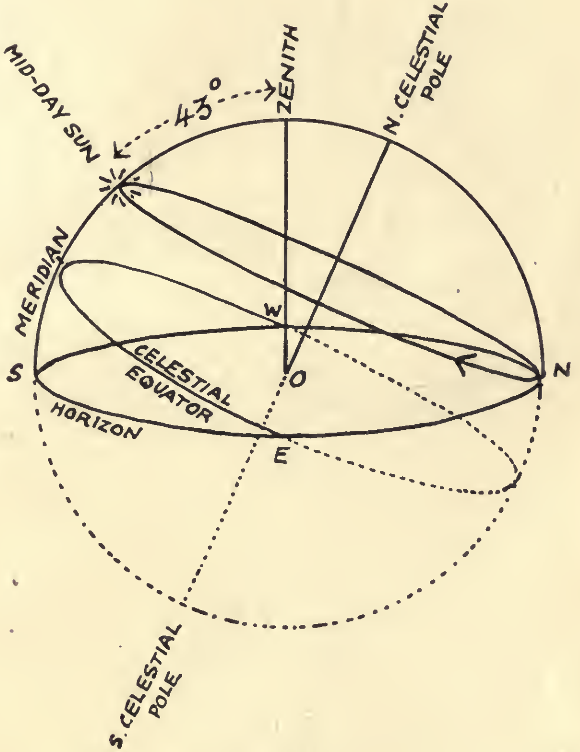


Fig. 13.

6. At every point further north than 23½° N. the day will be still longer and the night shorter. The opposite

will be the state of affairs at every point further south than 23½° S.

7. At every point on Lat. 66½° N. the day will last 24 hours, the sun just touching the N. horizon at midnight,

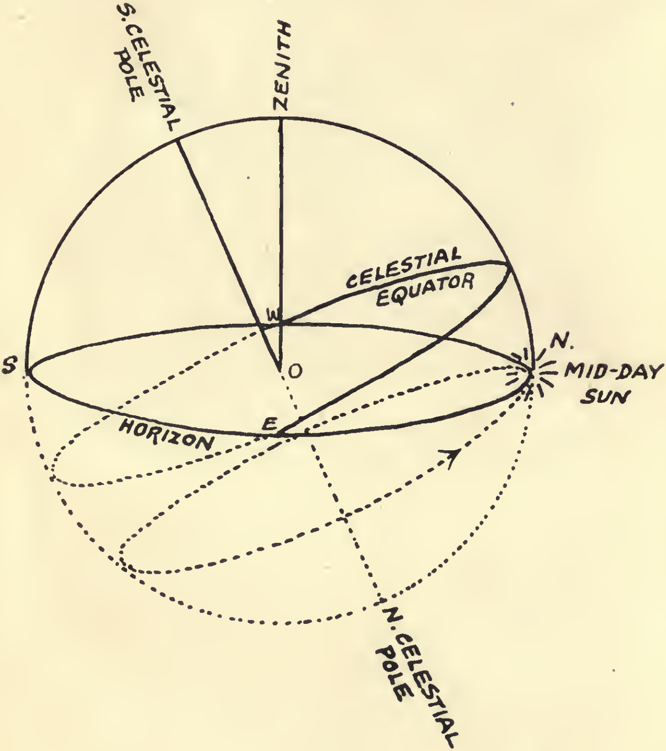


Fig. 14.

and being 47 degrees above the southern horizon at midday (Fig. 13.)

8. At every point on Lat. 66½° S. the sun will describe a complete circle below the horizon and there will be no daylight. The sun will just touch the N. horizon at midday and will be 47 degrees below the horizon at midnight. (Fig. 14.)

9. At every point north of Lat. 66½° N. the sun will describe a complete circle above the horizon but will be lower at noon and higher at midnight than at 66½° N.

10. At every point south of Lat. 66½° S. the sun will be below the horizon during the whole of the 24 hours.

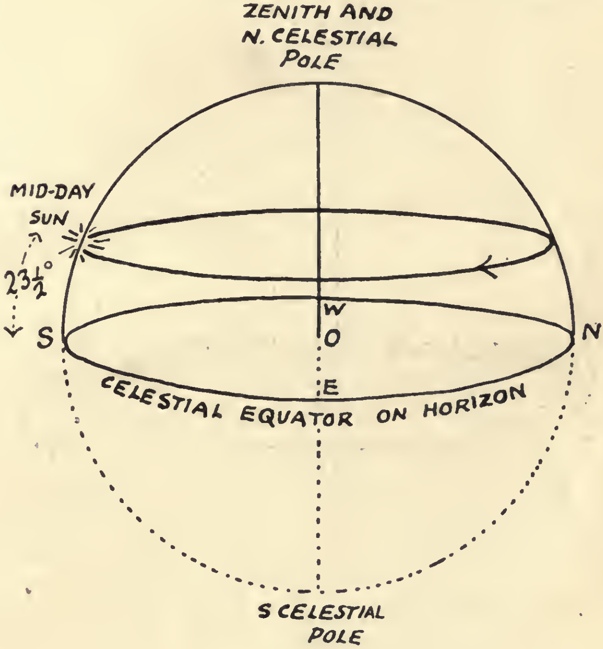


Fig. 15.

It will be further below the horizon at noon and not so far below at midnight as at Lat. 66½° S.

11. At the N. Pole the sun will describe a circle in the sky, being 23½° above the horizon at every moment in the 24 hours. (Fig. 15.)

12. At the S. Pole the sun will describe a circle which will be everywhere 23½° below the horizon. (Fig. 16.)

Winter in N. Hemisphere. Summer in S. Hemisphere. This state of affairs occurs on or about Dec. 21st, when the earth, having revolved along half of its orbit as measured from June 21st, will cause the sun to appear to occupy a position in the constellation of Capricorn (The Horned Goat).

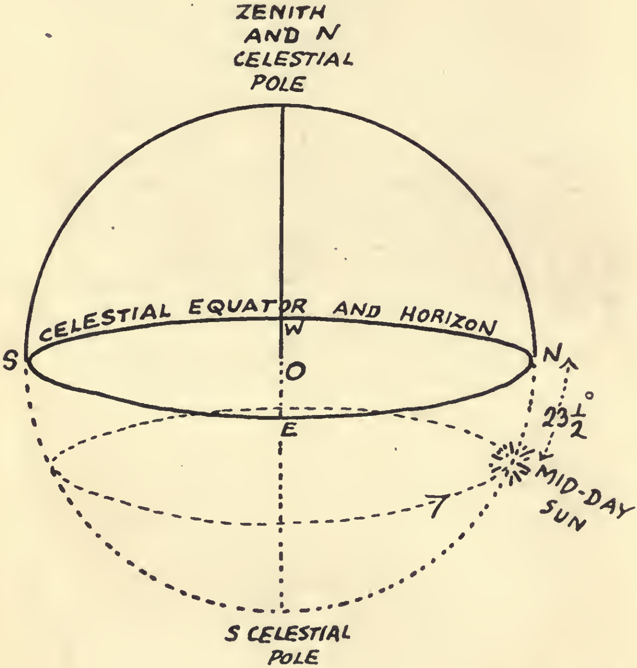


Fig. 16.

As the direction of the earth's axis does not alter during the year, it follows that the South Pole is now turned towards the sun and the conditions obtaining at any latitude are exactly similar to the conditions which on June 21st obtained at points in the opposite hemisphere equally removed from the equator.

Spring and Autumn. When the earth is midway between its summer and winter positions, the North Pole is turned neither towards nor away from the sun. A line joining the centre of the earth to the centre of the sun would be at right angles to the earth's axis. Consequently, the poles are on the border between the light and dark halves. Concerning this position the following facts are to be noticed:—

1. Every point on the equator has the sun in the zenith at noon, the sun being on the Celestial Equator.

2. At each pole the sun travels round on the horizon during the 24 hours.

3. At every other point on the earth the day and night are each 12 hours in length.

For this reason the spring and autumn positions of the earth in its orbit are called the Equinoxes. They occur on or near the 21st of March and the 23rd of September.

Variation of length of Day and Night. We have seen that at all points on the globe the lengths of the day and night vary during the year, except at the equator, where the day and night are equal in length throughout the year. Moreover the further we travel from the equator the greater the variation becomes, until at the poles the day is six months in length and the night six months.

March of the Perpendicular Midday-rays of the Sun. (Fig. 17.) On the 21st of March the midday sun will be overhead at the equator. This will be the vernal equinox. At this time the sun will be in the constellation of Aries.

By the end of June the midday sun will be overhead at latitude 23½° N. This will mark the Summer Solstice in the Northern Hemisphere and the Winter Solstice in the Southern Hemisphere. At this time the sun appears to be in the constellation of Cancer. From this point the sun's vertical rays return south again, but during the turning the length of the day varies very slightly for a few days. Hence the term Solstice.

By the end of September the vertical rays have arrived at the equator again, when the Northern Hemisphere has the Autumnal Equinox. At this time the sun is in the constellation of Libra.

The vertical rays continue their southern journey until they arrive at Lat. 23½° S. towards the end of December.

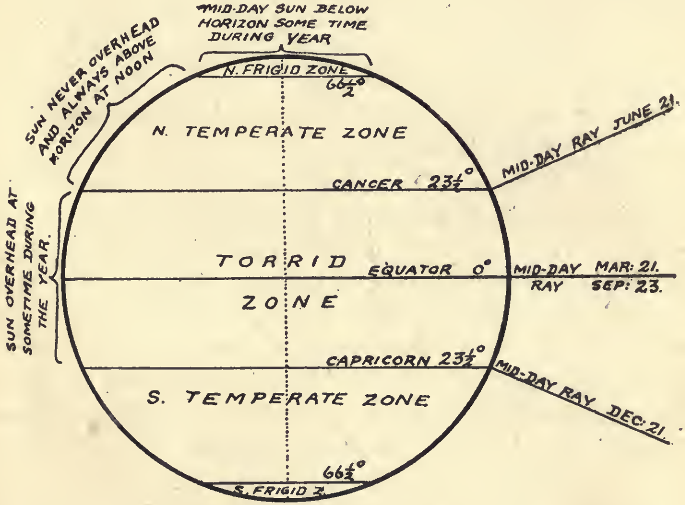


Fig. 17.

This is the Winter Solstice for the Northern Hemisphere and the Summer Solstice for the Southern Hemisphere. At this time the sun appears to be in the constellation of Capricorn.

By the end of March the sun is again over the equator.

Tropics. We have seen that the vertical rays of the sun move to and fro between the parallels 23½° N. and 23½° S., taking one year to complete the double journey north and south.

As the turning-points of the journey are on the parallels 23½° N. and 23½° S., these parallels are called the Tropics.

The parallel 23½° N. is called the Tropic of Cancer, because the sun is in the constellation of Cancer when it is overhead at Lat. 23½° N.

The parallel 23½° S. is called the Tropic of Capricorn, because the sun is in the constellation of Capricorn when it is overhead at Lat. 23½° S.

It will be seen that every place between the Tropics will have the midday sun overhead at two different times in the year. These times will divide the year into equal parts at the equator, while further and further north and south the difference between the two parts will become greater and greater, until the shorter part will disappear at the tropics.

Arctic and Antarctic circles. These are the parallels 66½° N. and 66½° S. respectively. On the polar sides of these latitudes all places have at least one day 24 hours long at midsummer and at least one night 24 hours long at midwinter. As we have seen before, the lengths of the midsummer day and midwinter night become greater nearer the poles, until at the poles they last six months.

Zones. The Tropics, the Arctic, and Antarctic circles divide the surface of the earth into five zones or belts:—

(i) **Torrid Zone** is the region between the Tropic of Cancer and the Tropic of Capricorn. It is 47 degrees wide (approximately 3250 miles). It includes all those positions where the midday sun is overhead on at least one day in the year. It is the zone of greatest heat.

(ii) **Temperate Zones.**

(*a*) North Temperate Zone is between the Tropic of Cancer and the Arctic circle. In this zone the sun is never overhead and the day never 24 hours in length. It is a zone of temperate heat but there is considerable difference between the temperatures at low and high latitudes in this zone. It is 43 degrees wide (3000 miles approximately).

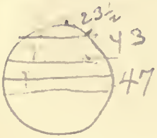
(*b*) South Temperate Zone is between the Tropic of Capricorn and the Antarctic circle.

(iii) Frigid Zones.

(*a*) North Frigid Zone is the surface of the earth within the Arctic circle. It is 47 degrees in diameter. Every place in this zone has at least one day 24 hours in length. It is a zone of great cold.

(*b*) South Frigid Zone is the surface within the Antarctic circle.

90
47
43



CHAPTER IV

CRUST OF THE EARTH

Cooling of the Earth. At one time the earth was a very hot liquid globe. When its temperature was sufficiently low, a crust formed on the surface of this molten globe. As shrinkage continued in the molten mass, the crust would endeavour to accommodate itself to the smaller volume of the fluid interior. But the solid crust would not shrink to such an extent as the fluid interior, and consequently it would be thrown into ridges with intervening depressions.

Now the flat-sided solid which has the largest surface for any given volume is a Tetrahedron, which is a solid bounded by four equilateral triangles. The solid which has the smallest surface for any given volume is a sphere, which may be said to be bounded by an infinite number of flat sides.

Therefore we can imagine the globe of molten liquid covered with a relatively non-contractile crust as passing through the forms of regular solids from that with an infinite number of sides, the sphere, to that with the fewest sides, the Tetrahedron.

We do not say it is actually compelled to assume a tetrahedral form. As a matter of fact, folds occur in the crust long before the ratio between the volume of the molten interior and the surface of the crust satisfy the conditions for a tetrahedral form. But it is quite possible that the major tendency of the cooling is to bring about a tetrahedral form though that form will never be reached because of minor tendencies, some due to lack of uniform constitution of the earth's crust, whereby folding and faulting occur.

At any rate the theory is interesting and suggestive, as the following facts show. Moreover it very materially helps one to remember the main facts of the configuration of the earth.

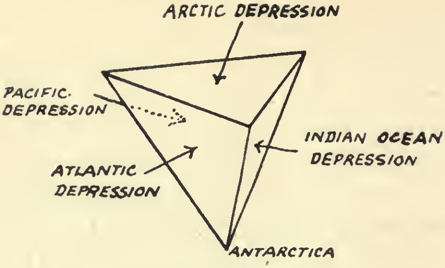
Configuration of Earth and Tetrahedral Forms. (Fig. 18.) On examining a globe we find a striking similarity between the positions of the large troughs and large continental cores compared with the centres of the triangular faces and the corners of a tetrahedron.

(i) The continental mass at the South Pole represents one corner of the tetrahedron.

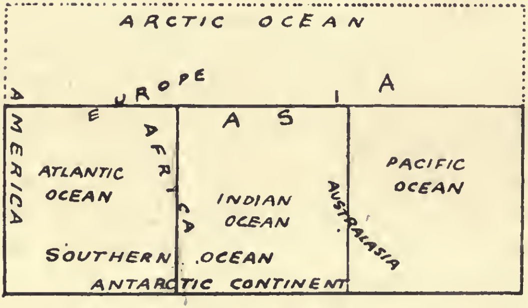
(ii) The ocean around the North Pole represents the centre of the opposite face of the tetrahedron.

(iii) A ridge of high land surrounds the Northern depression. This ridge stretches from Behring Sea to Persia, Caucasus, Carpathians, Alps, British Isles, across the shallow North Atlantic and across North America to the Behring Sea. This ridge obviously represents the three sides of the uppermost face of the tetrahedron.

(iv) Ridges of land are found connected with the



TETRAHEDRON



TETRAHEDRON ON MERCATOR'S PROJECTION

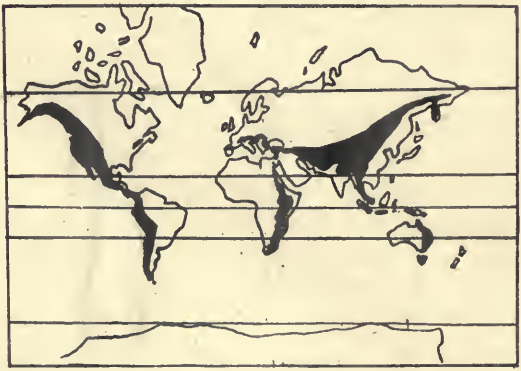


Fig. 18.

circumpolar ridge mentioned above. These ridges of land are three in number and are directed towards the South Polar Continent. They are:—

(*a*) Western Highlands of America,

(*b*) Eastern Highlands of Africa,

(*c*) South Eastern Highlands of Asia and Australasia.

There may be many objections to such a theory, but at least it assists one to grasp firmly the main features of the distribution of land and water.

Distribution of Land and Water.

(i) The Arctic depression, the deeper parts being occupied by an ocean—the Arctic Ocean, includes,—

(ii) The Great Northern Plains, which surround the Arctic Ocean, and are interrupted only by the shallow North Atlantic Ocean and Behring Strait, both of which are to be looked upon as drowned plains. The Great Northern plains of America and Eurasia slope northwards to the Arctic Ocean and are drained by large rivers which flow into it. (Yukon, Mackenzie, Hudson Bay Streams, Rhine, Elbe, and other rivers which flow across the drowned plain of the North Sea, Northern Dwina, Obi, Yenisei, Lena.)

(iii) Highland Ridges of the North Temperate Zone overlook the Great Northern Plains. The height of land in Eurasia is represented by plateaux and parallel ridges with longitudinal depressions—the Tarim depression being the chief. The great triangular plateau of Central Asia, including Pamir, Thibet, and Gobi regions, represents one of the culminating points of the land masses of the world and we may compare it with a corner of the tetrahedron. From this mass a ridge goes north-east to Behring Sea, while from the Pamir the Iranian Plateau, Anatolia, Caucasus, Balkans, Carpathians, and Alps are portions of the ridge stretching to the west. Thence, by way of the British

Islands and Telegraph ridge of the North Atlantic, the ridge crosses to North America where it is represented by the Lawrentian Highlands and the Height of Land. In America this old ridge is somewhat overshadowed by the much more imposing, but far younger, Rocky Mountain region.

(iv) South of this ridge which encircles the earth are three ridges directed towards the South Pole. These are:—

(*a*) Rocky Mountains and Andes, which extend from Alaska to the extreme south of South America.

(*b*) Highlands of Eastern Africa, which are more or less continuous from Asia Minor to the Cape.

(*c*) Mountain Axis of Further India, South-East Asia, Malay Peninsula, and the Great Dividing Range of Australia.

(v) Between these ridges are the great ocean troughs on which open the following river basins and plains:—

(*a*) Atlantic Trough receives the drainage from the Mississippi, Orinoco, Amazon, Plate, Mediterranean depression, Niger, and Congo. A depression which causes the Atlantic to communicate with the Arctic Ocean puts the Atlantic Basin in easy communication with many important river basins of the Great Northern Plain, Rhine, Elbe, Baltic Rivers, and rivers of Eastern Britain.

(*b*) Indian Ocean Trough receives the Tigris, Euphrates, Indus, Ganges, Irawadi, and drains the Australian Region, except the narrow Pacific slope.

(*c*) Pacific Trough is much deeper and wider than the others, though the actual Asiatic continental border is along the islands which extend from the Island of Borneo to Alaska. This trough is filled with water close up to the great mountain ridges, except in China, where the Great Plain of China is the only extensive region drained into the Pacific. The mountain axis of America and the

Dividing Range of Australia are close to the shores of the Pacific, and under conditions prevailing at present make the Pacific commercially insignificant as compared with the Atlantic.

(vi) To the south these ridges dip underneath the Southern Ocean which surrounds the globe between about 40° S. Lat. and the Antarctic continent.

(vii) The Antarctic continent in the South Polar Region.

Chief facts concerning Configuration.

(i) The greater proportion of the land surface of the globe is found in the Northern Hemisphere.

(ii) From the land masses of the Northern Hemisphere only three relatively small peninsular regions extend south of the equator. They are South America, Africa, and Australasia.

(iii) The large amount of land surface in the Northern Hemisphere gives it a greater range of temperature during the year than is found in the Southern Hemisphere, where the surface of the ocean is very great in comparison with the extent of the land surface.

(iv) The great plains of the Arctic depression are the coldest regions in the world, because:—

(*a*) They slope northwards away from the sun.

(*b*) They are open to the cold northerly winds.

(*c*) They are shielded by the Great Ridges of the Northern Hemisphere from the warm southerly winds.

These plains are also regions of low rainfall.

The Plain of Europe is the only part of this region which, owing to exceptional conditions—a part of the Ridge being drowned in the North Atlantic—permits a relatively mild climate to obtain, because warm moist winds enter from the Atlantic depression.

(v) Plains open on the three great depressions south of the Great Ridge of the North Temperate Zone. These plains possess an excellent climate which is warm and equable, because:—

(*a*) They slope South.

(*b*) They are shielded from the cold northerly winds by the Great Ridge lying to the North.

(*c*) They are open to the warm winds from the equatorial surfaces of the oceans lying in the great troughs (Atlantic, Indian and Pacific Oceans).

They are also regions of great rainfall, which, coming at particular seasons, floods many of the plains at regular intervals and renders a dense population and a high degree of civilization possible.

In these regions the various early civilized peoples were evolved—Chinese, Egyptians, Hindus, Chaldeans, Persians, Greeks, Romans, Mexicans, and Peruvians.

CHAPTER V

MAPS

[For a full account of the subject see the recent books by A. R. Hinks, published by the Camb. Univ. Press. *Maps and Survey*, and *Map Projections*.]

Base Line. In making an accurate map of a district it is necessary to measure a base line as accurately as possible.

A tape or wire made of "invar" is used. Invar is an alloy of nickel and steel: its coefficient of expansion is only one-tenth of that of steel. The tape is "hung under constant tension in the natural curve—catenary—supported at each end by frictionless pulleys suspended from trestles, and carrying near each end a divided scale which is read against marks carried on tripods set up along the line of the base" (Hinks).

Triangulation. Having a base line, the position of any point which can be seen from both ends of the base can be found by using a theodolite to measure the angles between the base line and the directions from the two ends to the point.

Knowing the length of the base line and the angles at the ends of the base line, it is easy to find by calculation the exact position of the point and the lengths of the sides of the triangle. The two sides of the triangle can now be used as base lines for further triangles, and in this way a whole region may be triangulated from a base line.

Map or Plan. A map or plan shows the relative horizontal distances between all places in the particular region it represents.

The actual distance is not shown, except on a perfectly level plain. However, the actual distance can be easily calculated from the horizontal distance, if the gradient is known.

Scale. It is necessary to know the relationship between the distances on the map and the distances represented in the region mapped.

The whole of the British Isles has been mapped on a scale of 25 inches to the mile. From this, maps on smaller scales, 6 inches, 1 inch, ½ inch, and ¼ inch to the mile, have been made.

The scale is often given as a representative fraction. Thus on a map drawn to a scale of 1 inch to the mile a distance of 1 inch represents a horizontal distance of 1 mile. There are 63360 inches in 1 mile. Therefore distances on the one inch map are 1/63360 of the actual horizontal distances. The fraction 1/63360 is the representative fraction.

A scale is always printed on the map and distances must be measured by means of this scale, for the paper may expand or shrink and if an independent measure is used a considerable error may be made.

Three Classes of Maps.

1. **Cadastral Maps** are drawn to a large scale, say 25 inches to 1 mile. "They show boundaries of property and individual buildings. They are required for local administration and taxation; the management of estates; the identification of property in legal documents; and for detailed affairs of every kind."

2. **Topographical Maps** "show the natural features of the country, hills and rivers, forests and swamps; and in addition such artificial features as man has added to the country, in the shape of towns and villages, roads, railways and canals, bridges and telegraphs. They serve as guides for travel, or for the operations of war." They are on a smaller scale than cadastral maps: say one inch to the mile.

3. **Atlas Maps** "are on scales still smaller. Most of the topographical details have been suppressed; only the principal ranges of hills and the main streams of the rivers, the chief towns, and perhaps the main lines of the railways can be represented, for they aim at representing on a single sheet a whole country, a continent, or even the world."

(HINKS.)

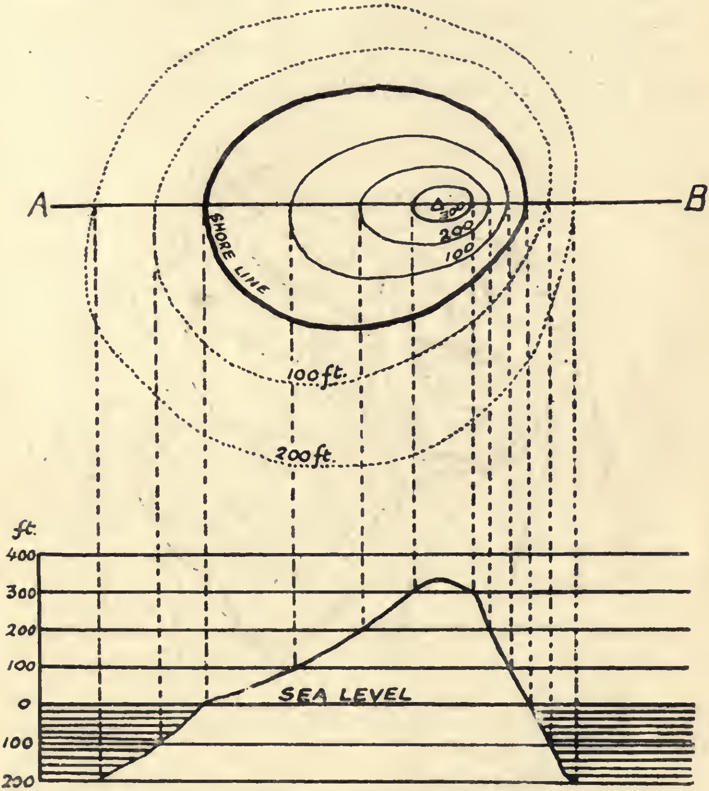
Relief.

1. **Contours** are lines joining points having the same height above the sea level or other base level.

Thus an island standing in a sea where there are no tides possesses one contour—the base level contour—marked off by the line where the land and sea meet. If the island were lowered 100 feet, another line would be marked by the new sea level 100 feet above the base level contour. Another depression of 100 feet would mark off a 200 feet contour, and so on (Fig. 19).

If the island were elevated 100 feet out of the sea, a contour of 100 feet would be marked off below the base level contour. If another elevation of 100 feet occurred a 200 feet contour would be formed, and so on.

If the island were perfectly conical these contours would be concentric, and a plan of the island contours would be a series of concentric circles, as the slope of the island surface would be equally steep on all sides. The contours would be at the same distance apart everywhere. It is evident that the steeper the slope, the nearer together will be the contours.



CONTOURED MAP AND SECTION

Fig. 19.

The contours of a river valley are characteristic. Each contour bends up the river valley and if it is lower than the source of the river it crosses the river. The contours of the tributary valleys open out of the main valley in the same way. This gives a hand-like appearance to a river valley system of contours. The lower contours are the inner ones nearer the stream (Fig. 20).

When the contours are slightly concave to the lower land, the feature indicated is an embayment.

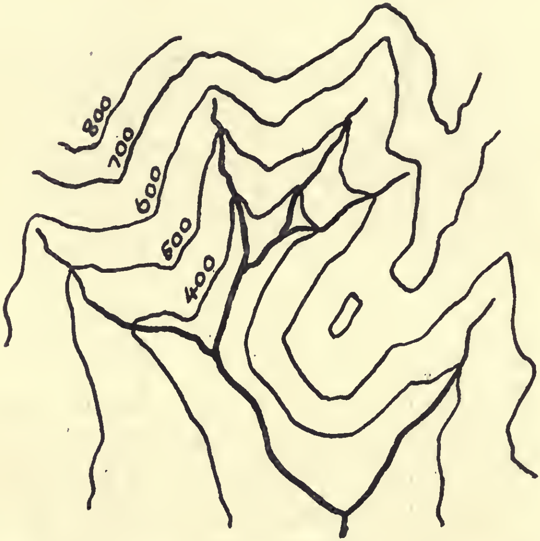


Fig. 20. Contoured valley.

A spur is the opposite of an embayment. On a spur the contours are convex towards the lower land, and along its edge the contours are often very close together indicating a precipitous slope (Fig. 21).

A ridge with peaks will show two or more island-like contour lines enclosed by the lower contours. The depression between the peaks is known as a saddle, or, if slightly

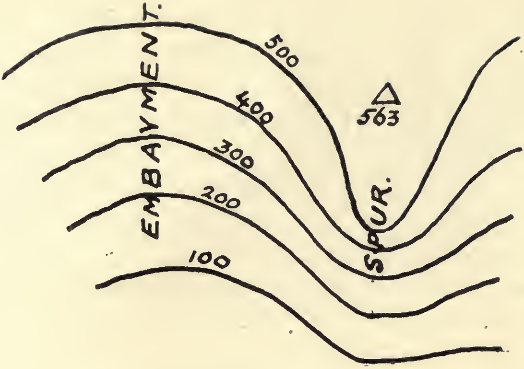


Fig. 21. △, trigonometrical station.

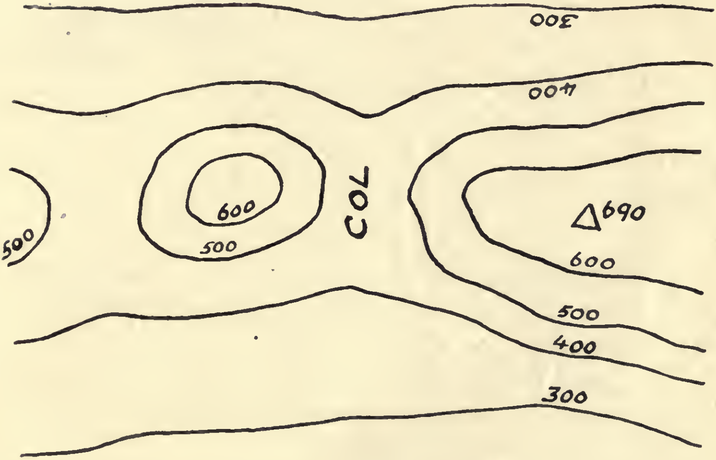


Fig. 22. Two peaks and col.

lower, a col. Still lower depressions are called gaps or passes (Fig. 22).

2. **Hachures** indicate slope, not height. They are short lines drawn directly down the slope. The steeper the slope, the thicker and closer together are the lines.

Thus on a hachured map, absence of shading indicates level ground: it may be a plain, or a plateau, or level ground at any altitude. The tops of hills and ridges are usually more or less level, and consequently on a hachured map are light (Fig. 23).

Hachures are useful to indicate minor inequalities which occur between the contour lines.

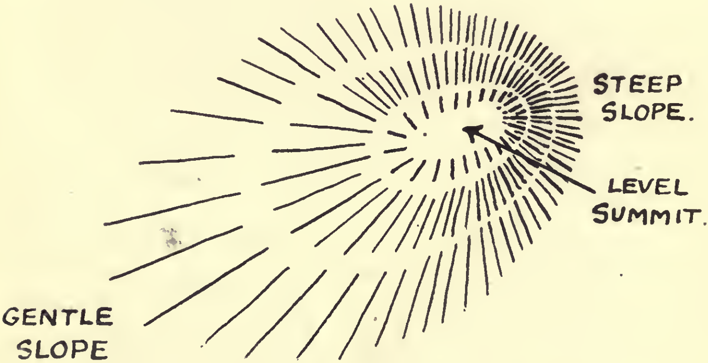


Fig. 23. Hachured hill.

3. **Hill-shading** produces very much the same effect as hachures. The slopes are coloured in rough proportion to their gradient with a brush or stump (Fig. 24).

4. **Layer Colouring.** A scale of graded colour tints is chosen, and all the ground between each pair of contours is coloured by a particular tint.

Position on the Globe. The position of a place on the globe is found by astronomical observations, which we have considered previously in dealing with latitude and longitude.

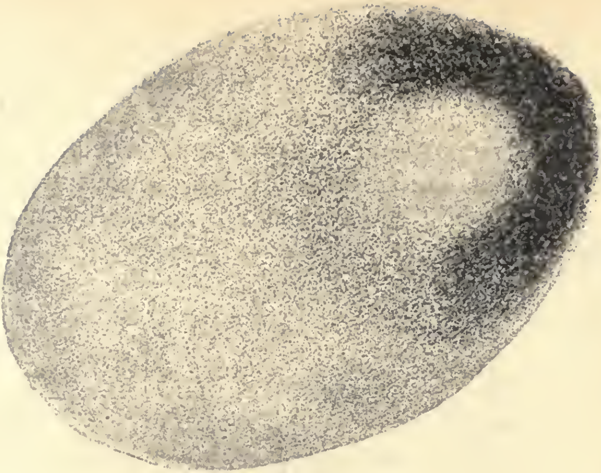


Fig. 24. Shaded hill.

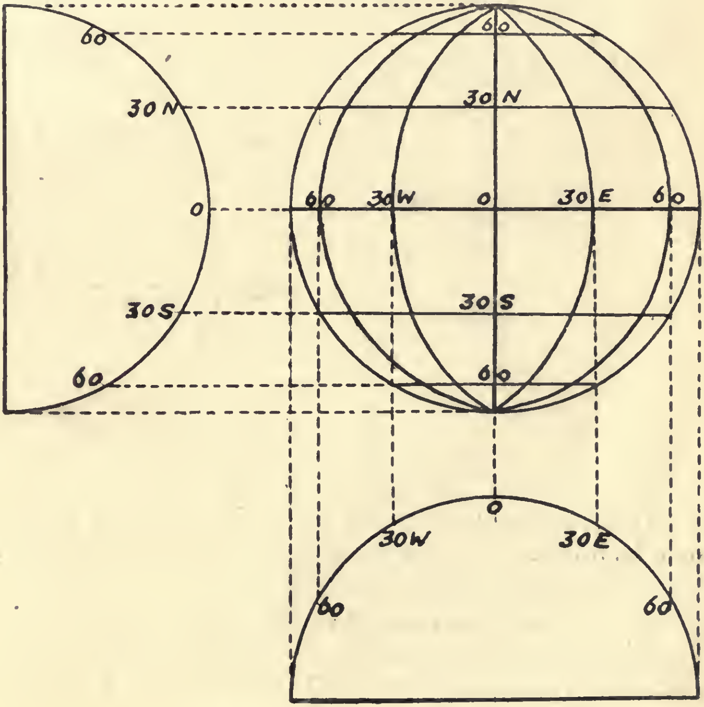


Fig. 25. Orthographic projection.

Projection. The surface of the earth can be represented with accuracy only upon a globe, but for very small areas the amount of curvature may be neglected.

Even with larger areas it is always convenient to make a map upon a flat surface and this necessarily makes it impossible to avoid errors.

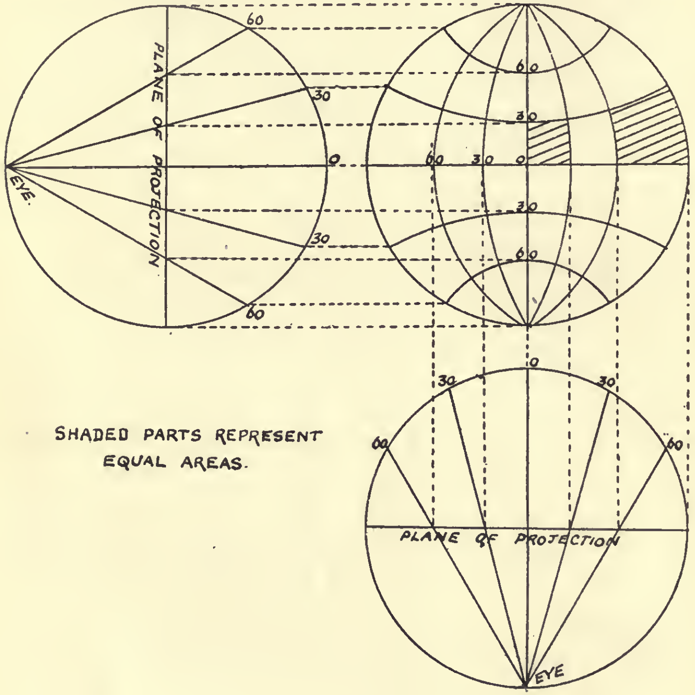


Fig. 26. Stereographic projection.

There are many ways in which the spherical surface may be projected upon a flat surface or plane of projection. The following are a few of these methods :—

1. **Orthographic** (Fig. 25). This projection shows the hemisphere as it would appear at an infinite distance from the eye. The appearance we get of the moon is practically

orthographic. Obviously only the central part of such a map is well represented, the outer parts being greatly distorted. It has considerable interest to astronomers, but for geographical purposes the orthographic projection has no merits whatever.

2. **Stereographic** (Fig. 26). This projection represents the appearance of the opposite hemisphere as seen from a point on the sphere opposite the centre of the hemisphere.

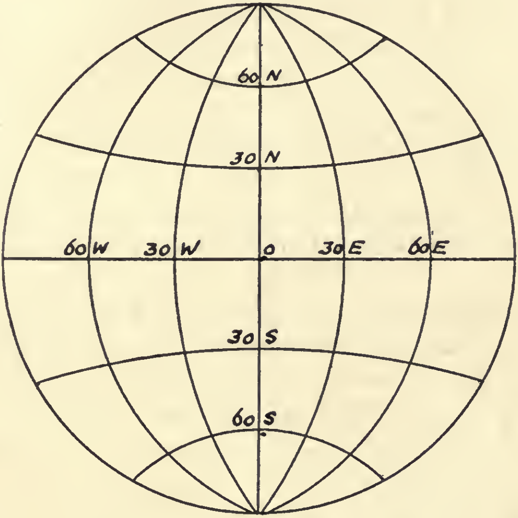


Fig. 27. Globular projection.

The plane of projection passes through the centre of the sphere, and is at right angles to the line joining the centre of the hemisphere to the point of observation. The following facts are to be noted :—

(*a*) The scale increases with distance from the centre, so that the outer parts are too large.

(*b*) The areas at a distance from the centre are exaggerated.

(*c*) Very small areas are not distorted in shape, but the shapes of large areas are not well shown.

This projection is useful for a map of a hemisphere on a small scale.

3. **Globular** (Fig. 27). This projection is often used in atlases for the World in Two Hemispheres. The central meridian and the equator are straight lines divided into equal parts. The circumference of the map is also divided into equal parts. The parallels and meridians are arcs of circles passing through corresponding points.

(*a*) As the parallels and meridians do not intersect at right angles, except at the equator and the central meridian, all areas are distorted in shape, except very small areas along these two diameters of the map.

(*b*) The outer parts of the map are too large, but the enlargement is not so great as in the stereographic. The projection has little or no interest from a geometrical point of view.

4. **Modified Globular.** In some of the smaller school atlases the central meridian and equator are divided in such a manner that the scale decreases from the centre of the map towards the periphery. This tends to make the map approximate more to an equal area map, but the distortion in shape is increased.

5. **Mercator.** In this projection all meridians and parallels are straight lines intersecting at right angles. It follows that the scale along the parallels increases very rapidly with distance from the equator. The parallels are drawn at such a distance apart that the scale at any point along the meridian is the same as the scale along the parallel. Consequently the distance between successive parallels increases rapidly with the latitude, the poles being at infinity.

Mercator's projection is a cylindrical projection, which is a special case of a conical projection, the equator being the standard parallel and the apex at infinity. Note :—

(*a*) This projection is invaluable in navigation, for the compass course between any two points is the straight line joining them. It must be remembered that this will not be the shortest or great circle course, except along a meridian or along the equator.

(*b*) This projection gives the true shape of any small area, but the shapes of large areas especially in high latitudes are greatly distorted.

(*c*) The areas are very greatly distorted especially in high latitudes.

(*d*) The true direction of a line on the map can be seen at a glance and hence the trend of isobars, isotherms, isohyets, isoclinic and isogonic lines, as well as winds, can be well shown on maps of the world drawn on Mercator's projection. In these distribution maps, however, the distortion of area is a great drawback.

Mollweide's map (*vide infra*) is an equal area map, but, for a distribution map, its drawback is that true direction is not obvious at a glance.

6. **Simple Conical** (Fig. 28). The meridians are straight lines converging to a point, the vertex, the parallels being concentric circles described about that point. One of these parallels is taken as the standard parallel and is correctly divided according to scale. The central meridian is also correctly divided according to scale, the concentric parallels being drawn through the points on it. The following are the chief facts to be noticed concerning this projection :—

(*a*) The scale along every meridian is correct.

(*b*) The scale along the standard parallel is correct.

(*c*) The scale along the other parallels increases with their distance from the standard parallel.

(*d*) The pole is not a point but an arc.

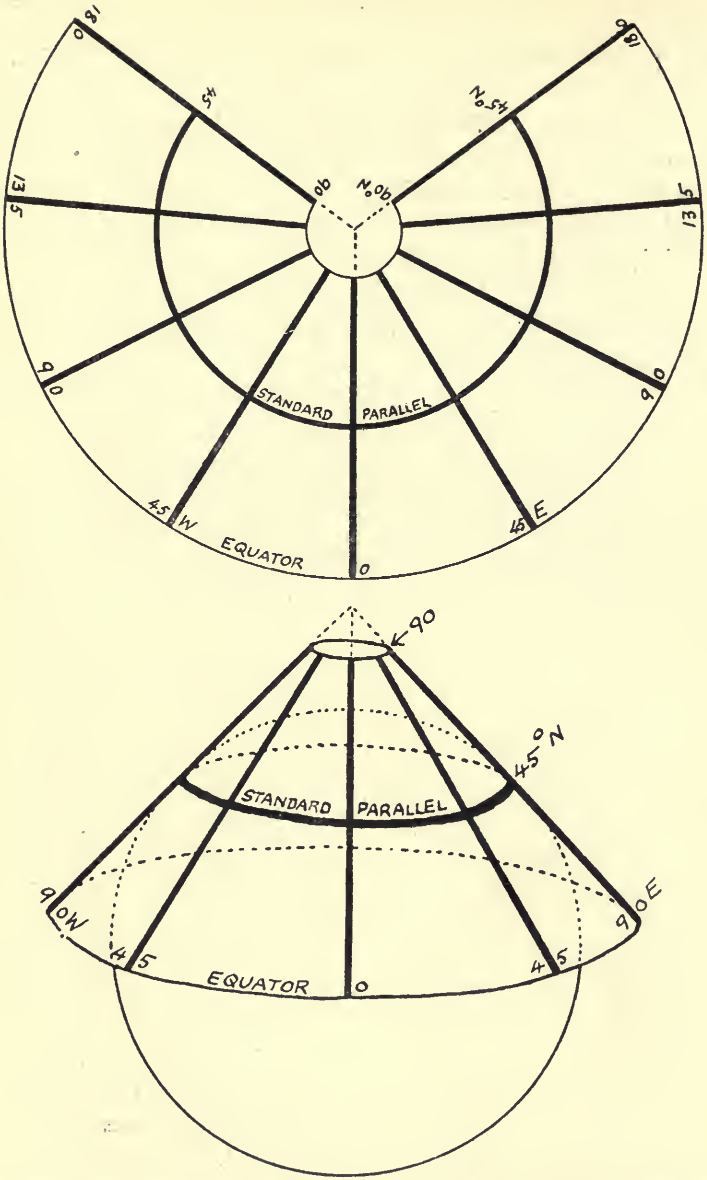


Fig. 28. Conical projection of the N. hemisphere. Lines true to scale are thickened.

(*e*) The smaller the extent in latitude, the better will be the map.

(*f*) If the map is wrapped around the globe so that the standard parallel coincides with the corresponding parallel on the globe, it will be a truncated cone tangential to the globe. The upper edge of the truncated cone will represent the pole. It is therefore clear that such a projection cannot be derived by projection from the centre of the globe.

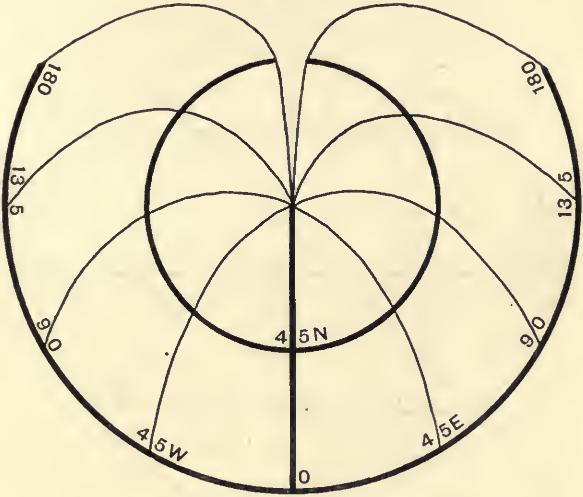


Fig. 29. Bonne's projection of the N. hemisphere. Lines true to scale are thickened.

This projection is very much used for small atlas maps of countries and continents.

7. **Bonne's Projection** (Fig. 29). This is a modified conical projection. All the parallels are concentric and are truly divided. The central meridian is truly divided. The other meridians are curves drawn through the corresponding points on the parallels. The facts to be noted are the following :—

(*a*) The scale along all parallels is true.

(*b*) The scale along the central meridian is true, but the scale along the other meridians increases with distance from the central meridian.

(*c*) The distortion in shape increases with the distance from the central meridian.

(*d*) The projection is equal area.

(*e*) The pole is a point.

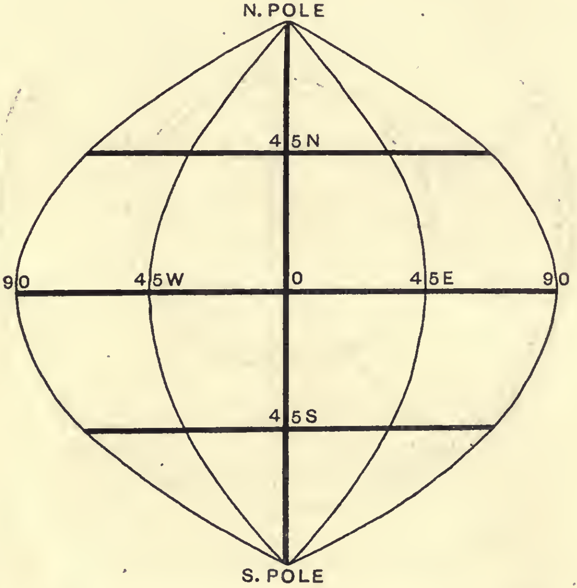


Fig. 30. Sanson-Flamsteed's projection of a hemisphere.

This projection is very commonly used for atlas maps of continents.

8. **Sanson-Flamsteed's Projection** (Fig. 30). This is Bonne's projection, where the parallels are straight lines. It is often used for maps of Africa and South America, which extend north and south of the equator.

9. **Zenithal Equidistant** (Fig. 31). Imagine the conical projection to flatten until it becomes a plane, the vertex coinciding with the pole. The meridians become radii. They are divided truly, and the circular parallels are drawn through the corresponding points on the meridians. Note :—

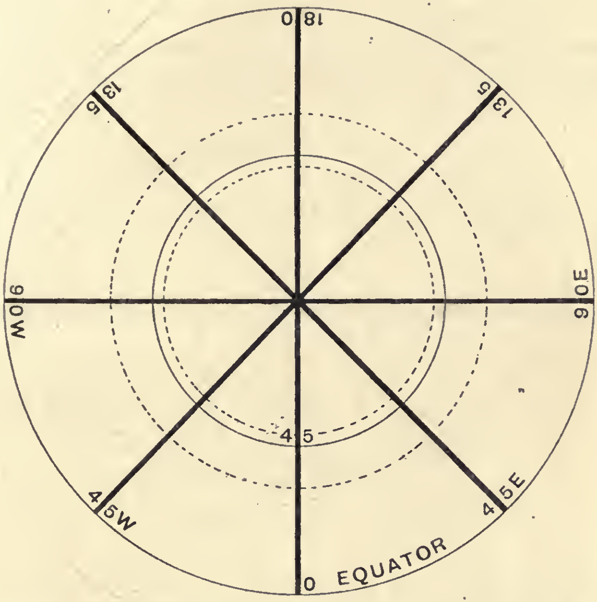


Fig. 31. Zenithal projection of the N. hemisphere. Lines true to scale are thickened. The dotted circles are the equator and the 45th parallel true to scale.

(*a*) The scale along all the meridians is true.

(*b*) The projection shows the true bearing of any point from the pole.

(*c*) The scale along the parallels increases with distance from the pole. Hence it is not an equal area projection.

This projection is usually employed for polar regions, where the extent in latitude is not great.

It is also employed for atlas maps of the continents, the plane of projection being made tangential to the centre of the map. In such a case the circles and radii of the projection are, of course, not parallels and meridians.

10. **Mollweide's Projection** (Fig. 32). This is an equal area projection. The equator is a straight line. The Greenwich meridian (or any other convenient meridian) is a straight line half as long as the equator and bisecting it at right angles. The 180° E. and 180° W. meridians form an ellipse, the equator being its major axis and the Greenwich meridian its minor axis. The 90° E. and 90° W. meridians together form a circle. The meridians between 90° E. and 90° W. form ellipses which have the Greenwich meridian for their common major axis. The other meridians are halves of ellipses which have their major axes along the equator. The parallels are straight lines and are drawn at such distances from the equator that the areas intercepted by them are equal to the corresponding belts on the globe.

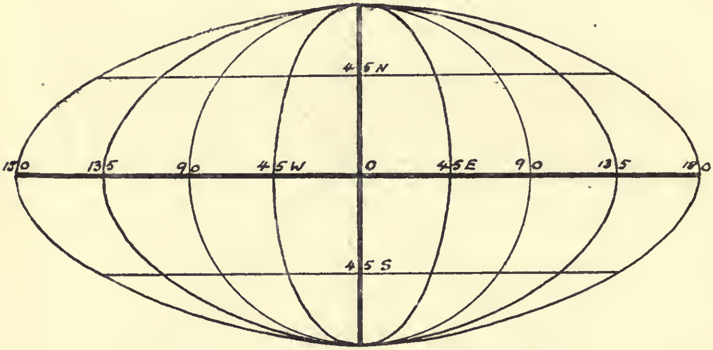


Fig. 32. Mollweide's projection.

This projection avoids the disadvantages of Mercator's, except the distortion of shape, which is extreme near the edge of the map.

It is sometimes used for distribution, but the directions of prevailing winds, etc., are not obvious at a glance and one cannot readily see whether a place is east or west of another.

Magnets. If a magnetised bar of steel is balanced on a point so that it can move in a horizontal plane, it is found to set approximately in a north and south line. The same end always points to the north. A magnet mounted in this way is termed a compass.

Such an instrument is obviously of great use in finding direction when the sun or stars are obscured by clouds, or when it is not convenient to make astronomical observations to find direction.

The compass is invaluable to travellers in an unmapped region, and to navigators.

Magnetic Declination. The direction in which the compass needle sets is called the magnetic meridian. At most points on the globe the magnetic meridian does not coincide with the geographical meridian. Consequently it is necessary to know the angular distance between these two directions for any place. This angular distance is known as the Magnetic Declination at the place of observation (Fig. 33).

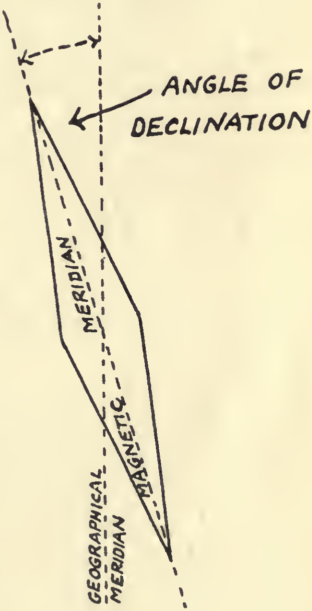


Fig. 33.

Not only does this angular distance vary from place to place, but it is also subject to considerable variation from time to time.

The distribution of magnetic declination is shown by **isogonic lines**, which are lines drawn through points of equal magnetic declination. A line of no declination is termed an **agonic line** (Fig. 34).

Magnetic Inclination. If a balanced magnetic needle is freely suspended about its centre of gravity it will "dip" away from the horizontal at most places on the earth (Fig. 35). In the greater part of the northern hemisphere its N. end will dip downwards. In the greater part of the Southern Hemisphere its S. end will dip downwards. The amount of dip varies from place to place. The distribution of magnetic dip is shown by **isoclinic lines**, which are drawn through points where magnetic dip is equal. The line of no dip is termed the **aclinic line**. The aclinic line is

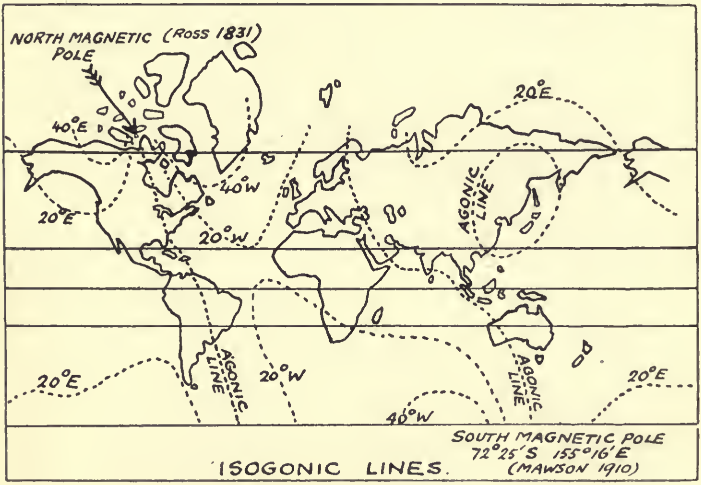


Fig. 34.

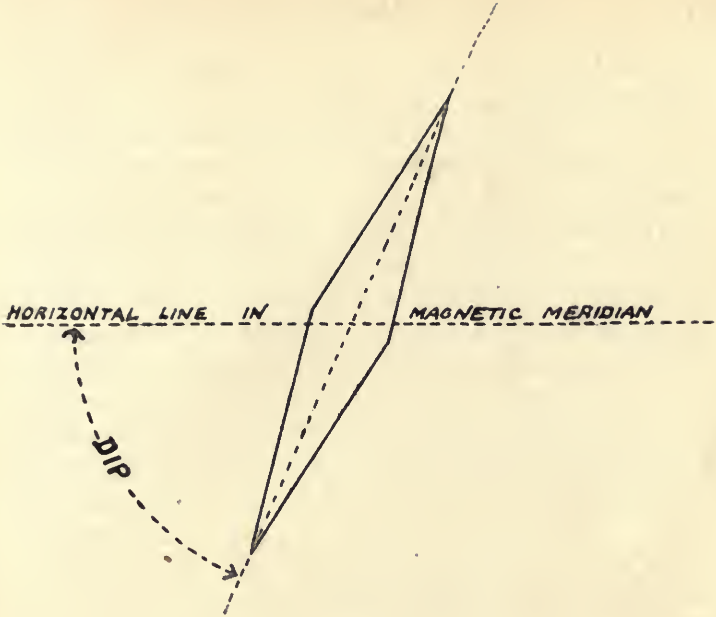

HORIZONTAL LINE IN MAGNETIC MERIDIAN
DIP

Fig. 35.

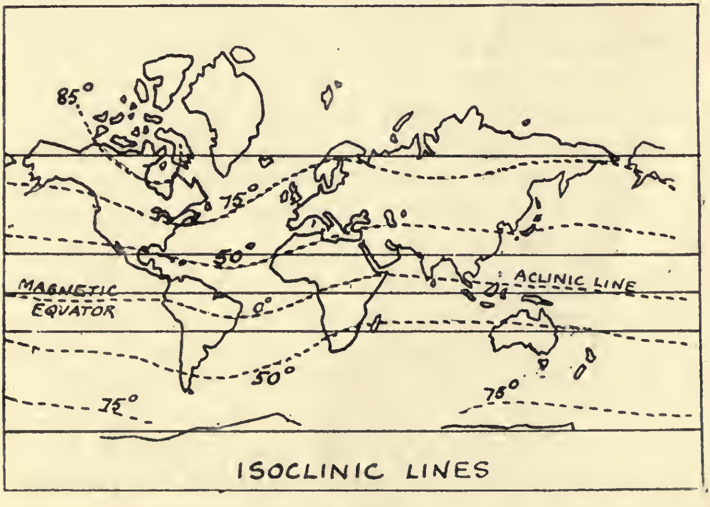

85°
75°
50°
MAGNETIC EQUATOR
0°
ACLINIC LINE
50°
75°
75°
ISOCLINIC LINES

Fig. 36.

between the tropics but only very roughly follows the equator (Fig. 36).

The magnetic poles, where the needle sets vertically, are at a considerable distance from the geographical poles (Fig. 34).

The use of steel in the construction of vessels brings another disturbing influence on the magnet and altogether it becomes very difficult, if not impossible, to find direction accurately with the compass. There has been invented a Gyro Compass which sets in the geographical meridian and is of course uninfluenced by variations in the magnetic field. If the expense of its construction could be lessened, it is thought that it would rapidly displace the magnetic compass.

CHAPTER VI

CLIMATE (TEMPERATURE)

Atmosphere. An ocean of air covers the earth. This atmosphere is at least 200 miles deep; but, because air is compressible, the air at the surface of the earth is denser than the upper layers, the density decreasing with altitude, so that one half the atmosphere is below 3½ miles, ¾ of the atmosphere is below 7 miles and $\frac{15}{16}$ of it is below 14 miles.

The composition of the air is :—

Nitrogen	79	per cent.	approx.
Oxygen	21	„	„
Carbon dioxide	.00·03	„	„
Water-vapour	variable		

It is found that the air has this composition in all regions, and therefore the distribution of life is not affected by any variation in these gases.

But water vapour in the air is very variable in amount.

When air contains as much water vapour as it can hold at any particular temperature and pressure, it is said to be saturated at that temperature and pressure.

The absolute humidity of the air at any time is the amount of water vapour present.

The relative humidity of the air at any time is the amount of water vapour present, compared with the amount of water vapour it would hold if saturated at the same temperature and pressure.

The distribution of plant life depends partly upon the relative humidity of the air.

If the relative humidity is much above 70 per cent. the air is unpleasantly moist; if the relative humidity is below 70 per cent. the air is unpleasantly dry.

Temperature of the Atmosphere. The temperature of the atmosphere at any moment varies from place to place, and at any place it varies from time to time. As the temperature of the atmosphere is one of the chief factors in the distribution of living things, it is necessary to obtain facts concerning it. The two most important instruments are the maximum and minimum thermometers.

A maximum thermometer usually contains mercury. In the bore of the tube is a small steel rod which fits the tube loosely. The thermometer is hung so that the tube is horizontal. As the mercury expands, it pushes the steel index along, but as the mercury contracts, it leaves the index in position, so that the end of the index nearest the mercury indicates the highest temperature since the thermometer was last set. The thermometer can be set either by slightly inclining it, or by drawing the index to the mercury by means of a magnet.

A minimum thermometer is usually filled with alcohol. In the bore of the tube is a very light dumb-bell shaped index. The surface of the alcohol draws the index back

.0003

towards the bulb as the alcohol contracts, but leaves it in position as the alcohol expands. Consequently the end of the index nearest the surface of the alcohol indicates the minimum temperature since the thermometer was set.

A continuous curve thermometer is sometimes used. It is an arrangement by which the expansion and contraction of a metal are recorded by a lever, which writes on a revolving drum covered with graph paper. These instruments are not so reliable as liquid thermometers, but they give a continuous curve, so that the temperature at any moment can be found by examining the curve.

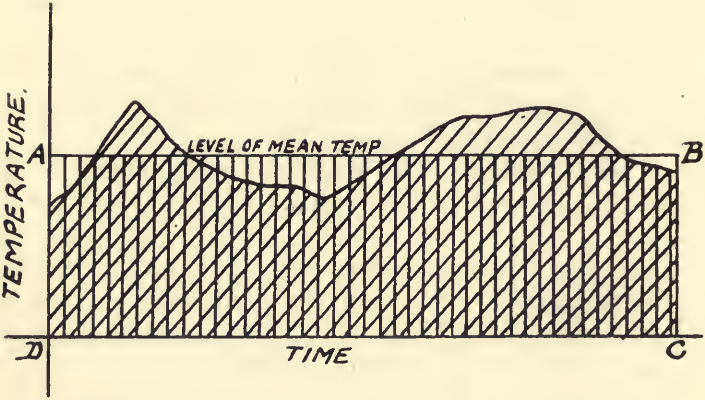


Fig. 37. Area shaded vertically equals area shaded horizontally.

Mean temperature can be found by taking the sum of a number of consecutive readings and dividing by the number of readings. It is evident that the smaller the interval between the consecutive readings, the more accurate will be the result. For example, in the given figure (Fig. 37) let the curved line represent a continuous curve of temperature, and let *AB* be drawn so that the rectangle *ABCD* be equal in area to the shaded area between the curve and

DC. Then *AD* will represent the mean temperature. But to obtain this result an infinite number of readings would need to be taken. This is impracticable.

The mean of 86,400 consecutive readings at intervals of one second would give a very close approximation to the true daily mean temperature: the mean of 1440 consecutive readings taken at intervals of one minute would be a less close approximation; and so on.

It is found that the mean of the maximum and the minimum temperatures recorded during 24 hours is quite near enough for ordinary purposes.

The daily range of temperature is the difference between the daily maximum and daily minimum temperatures.

The mean temperature of any month is the mean of all the mean daily temperatures during that month. Those of January and July are the most important for our purpose.

The annual mean temperature is the mean of the mean temperatures of all the months, or, more roughly, the mean of the mean temperatures of January and July.

The mean annual temperature is the mean of a number of consecutive annual mean temperatures.

Isotherms. An isotherm is a line joining places which have the same temperature at the same time.

Isotherms may be drawn to show:—

(i) Mean annual temperature.
(ii) Mean July temperature.
(iii) Mean January temperature.

It must be clearly understood that two places may have the same mean annual temperature, but their January and July mean temperatures may differ very widely. The following are two such places:—

	January	July	Range	Mean
Kootenay Valley B.C.	25° F.	75° F.	50° F.	50° F.
Isle of Wight	40° F.	60° F.	20° F.	50° F.

The Kootenay Valley has a severe continental climate, the Isle of Wight a mild relatively insular climate.

Circumstances Affecting Temperature. Of the many conditions affecting temperature the following are the chief:—

1. **Latitude.** Owing to the rotundity of the earth, the sun's rays are more oblique at some places than at others. At the equator the rays are more nearly vertical on an average throughout the year than at places nearer the poles.

The more oblique the rays, the larger will be the area over which the heat is spread, and consequently the lower will be the temperature (Fig. 38). It is for this reason that the average annual temperature becomes lower further and further away from the equator.

Moreover, the more oblique the rays, the greater will be the thickness of the atmospheric layer through which they will have to pass.

At the equator the mean annual temperature is about 80° F. At the tropics it is about 70° F.: at 50° north and south about 45° F. Along the arctic circle it is 35° F. over the Atlantic, but declines to 10° F. over North America and North Asia. Along the Antarctic Circle it is about 30° F.

As a general rule, the further removed from the equator, the colder will be the climate.

2. **Slope.** Slope produces its effect in the same way that latitude does: by determining the obliquity with which the sun's rays strike the surface. In the Northern Hemisphere the southern slope is always warmer than the northern, because the southern aspect decreases the obliquity of the sun's rays, while the northern aspect increases the obliquity. On a small scale this is evident when one observes the melting of snow or the disappearance of hoar frost from the house tops. The southern slope of

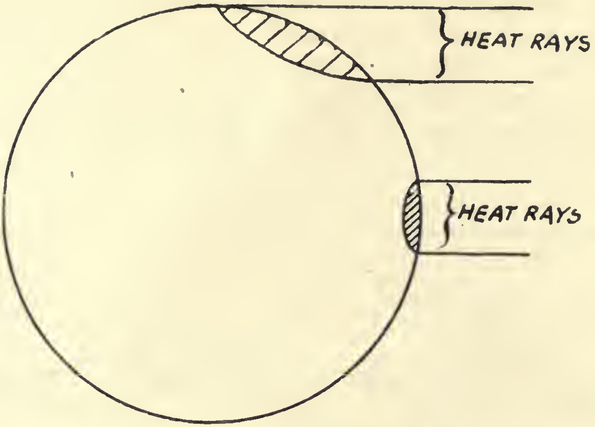


Fig. 38. Shaded areas receive equal amounts of heat.

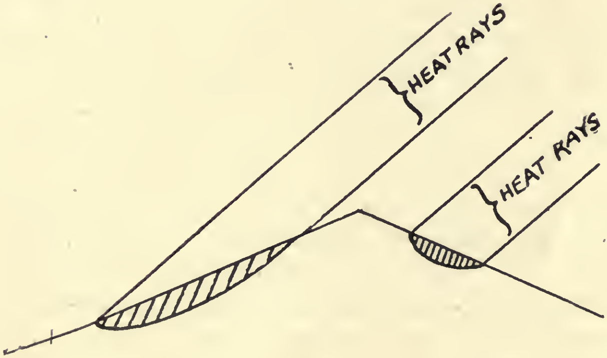


Fig. 39. Shaded areas receive equal amounts of heat.

the roof always loses its snow more rapidly than the northern side when the sun shines. The southern—Italian—slope of the Alps is much warmer than the northern—Swiss—slope (Fig. 39). Similar differences are found on the Caucasus and the Himalayas, and, in fact, on the opposite sides of all mountains which run east and west.

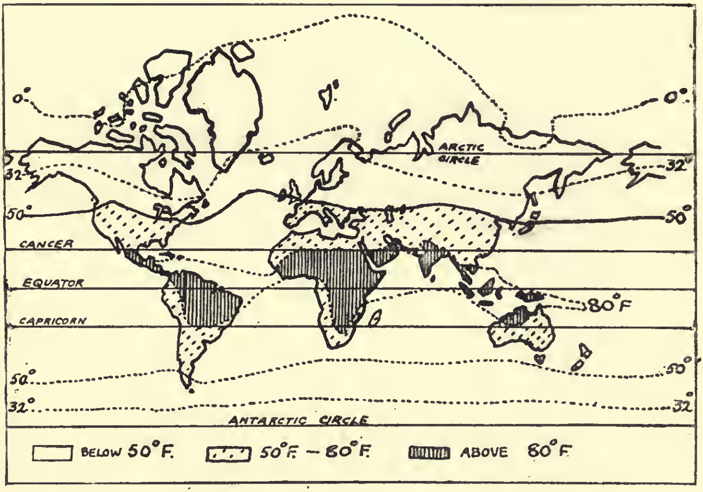


Fig. 40. Mean annual temperature.

It can easily be seen that in the Southern Hemisphere the northern slope is warmer than the southern.

In New Zealand fruit ripens best on a northern slope, whereas in England a southern aspect is the more favourable.

3. **Altitude.** Dry dustless air allows heat rays to pass through without absorbing them, except to a slight extent. The air is densest nearest the sea level. The lowest layers of the atmosphere also contain the largest amount of water vapour and dust. Dust and water vapour absorb the

heat rays. Thus the heat rays will pass through the atmosphere scarcely raising the temperature of the upper layers, but lower down the denser and more vapour- and dust-laden air will absorb more of the heat. But by far the greater amount of heat is absorbed by the surface of the earth. The heated surface of the earth warms the air in contact with it. It also radiates heat upwards into the air. Of this heat the lower layers of the air will absorb most, while, of that which reaches the upper layers, very little will be absorbed.

The important fact to remember is that the radiation from the sun heats the earth, which in its turn warms the air in contact with it.

Therefore, as a general rule, an increase in altitude causes a decrease in temperature. The rate of decrease is about 1° F. for a rise of 300 feet.

At a certain height above sea level the temperature of the air will be below freezing point. At this height water can exist only in the form of ice.

This height is 16,000 feet at the equator, 8000 or 9000 feet on the Alps, 4000 feet in Britain, and continues to decrease towards the poles, ultimately reaching the sea level.

The limit of perpetual snow, or snowline, is the height above which all the snow is never melted. This is not determined solely by altitude, but in a great measure depends on the amount of snow which falls. The snowline is lower, the larger the snowfall.

The effect of elevation on climate is shown in the case of Quito, which is between 9000 and 10,000 feet above the sea level. Though Quito is situated on the equator, its mean annual temperature is about 55° F., which is very nearly equal to that of Cornwall and S.W. Ireland.

Moreover, Europeans in India resort to hill stations during the summer. The best known of these are Simla and Darjeeling. Many Europeans become tea-planters because the steep hill-sides are suited to the cultivation of the tea-plant.

4. **Proximity to the Sea.** The specific heat of water is much greater than that of land: consequently the temperature of water does not rise so high as that of land during the summer, nor does it sink so low during the winter. On this account the further a place is from the sea, the hotter it is in summer and the colder in winter. The following table shows this:—

	Summer	Winter
Milford	60° F.	43° F.
Carmarthen	61° F.	41° F.
Newport	62° F.	40° F.
Swindon	63° F.	39·5° F.
London	64° F.	38·5° F.

5. **Prevailing winds.** It is clear that winds from the sea will lower the summer temperature and raise the winter temperature of a place. In fact, proximity to the sea is a condition which of itself has little effect on climate unless the prevailing winds at that place come from the sea. The winter temperatures on opposite shores of the North Atlantic illustrate this.

In this region the prevailing winds between 40° and 60° North lat. blow from the S.W. They are known as the S.W. antitrades. They blow towards western Europe, but away from North America. As a result, the winter temperatures of places on the western coast of Europe are higher than the winter temperatures at places on the eastern coast of America in corresponding latitudes.

St. of Belle Isle	10° F.	St. of Dover	40° F.
Halifax	20° F.	Bordeaux	45° F.
New York	32° F.	Oporto	50° F.
Cape Hatteras	45° F.	St. of Gibraltar	55° F.

6. **Direction of Mountain Chains.** If a mountain

chain runs in a direction at right angles to that of the prevailing winds, it exerts a considerable influence on temperature.

Thus the Norwegian mountains prevent the S.W. anti-trades from reaching Sweden until they have been compelled to rise and deposit their moisture. Consequently the winter temperature of Sweden is considerably lower than that of Norway. Again, during the summer the mountains prevent the mild winds from the sea from entering Sweden, which in consequence has a higher summer temperature than is found in Norway.

The Alps shield the plains of Northern Italy from the cold northerly winds.

The Himalayas are so high that they deflect the S.W. monsoon and cause it to blow up the valley of the Ganges, tempering a far greater area of Northern India than would otherwise be the case.

The climates on opposite sides of the Pennine Chain illustrate this, particularly during the winter, Yorkshire being much colder than Lancashire.

7. **Vegetation.** About 80 per cent. of a plant body consists of water. Moreover, plants are continually transpiring, and this lowers the temperature of the plant and of the air. Consequently vegetation acts like a sheet of water and the denser the vegetation the greater will be its effect in tempering the climate.

The hottest regions during July are the barren regions, where absence of water in soil and vegetation prevents the possibility of any of the heat being rendered latent.

Such regions are the Sahara, Arabia, Syria, Iran, Gobi, in the Old World, and the Great Basin in the west of the United States.

In January the hottest regions are the Kalahari and Australian deserts.

It must be clearly understood that absence of moisture causes absence of vegetation, which in its turn causes excessive heat.

The temperature of the climate of any place is determined chiefly by latitude and altitude, the other factors being of relatively minor importance.

July Isotherms (Fig. 41). During July the perpendicular rays of the sun will strike the earth near the Tropic of Cancer, and if the surface of the earth were uniform in character, then all places along the Tropic of Cancer would have the same temperature, and the isotherms would coincide with parallels of latitude. Moreover, the zone of greatest heat would be a continuous belt encircling the earth along the tropic.

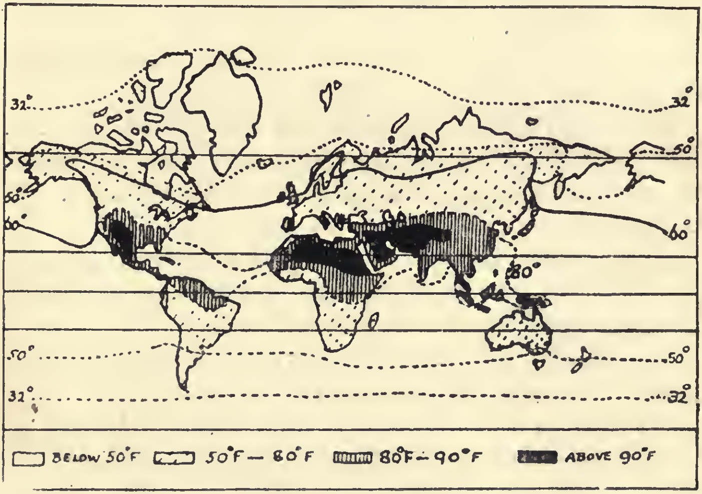


Fig. 41. July temperature.

But when we examine a map on which the July isotherms are marked, we do not find such uniformity.

The chief facts we notice are as follows :—

(i) The regions of greatest heat are on the land masses of the Old and New Worlds which lie along the

Tropic of Cancer. These regions are Mexico and the region immediately north of it, North Africa, Asia Minor, Arabia, and Central Asia. We note, moreover, that in these regions hot deserts are found wherever rainfall is low. The hot deserts are the Great Basin between the Sierra Nevada and the Plateaux of the Colorado and the Columbia, the Sahara, the Arabian and Syrian Deserts, and the Deserts of Iran and Gobi. Smaller deserts are found in India (Thar Desert) and in the Caspian region.

(ii) The intermediate regions of the Atlantic and Pacific Oceans lying along the tropic are comparatively cool.

The Red Sea, cutting off the hot African region from the hot Asiatic region of greatest heat, as well as the Persian Gulf, forming an isothermal "gulf" in the Asiatic region of greatest heat, are of great interest in showing clearly the effect of bodies of water on temperature.

(iii) If we follow any parallel of latitude in the Northern Hemisphere across a mass of land, we notice that, as we go away from the sea, the July temperature becomes higher. Consequently in July the isotherms in the Northern Hemisphere bend northwards over the continents and southwards over the oceans.

Examine especially the course of the 60° F. isotherm, which crosses the Midlands of England.

Also compare the July temperatures of the following places, which are approximately 50° N. of the equator :—

London, Berlin, Warsaw, Saratov, Irkutsk, Nikolaievsk, S. Point of Kamchatka, Vancouver, Calgary, Winnipeg, Quebec, St John's.

Also examine the 60° F. isotherm which crosses the British Isles and note that it bends north over Ireland as far as **Cavan**, south over the Irish Channel as far as **Pembroke**, and north again over England as far as **Westmorland** (Fig. 42).

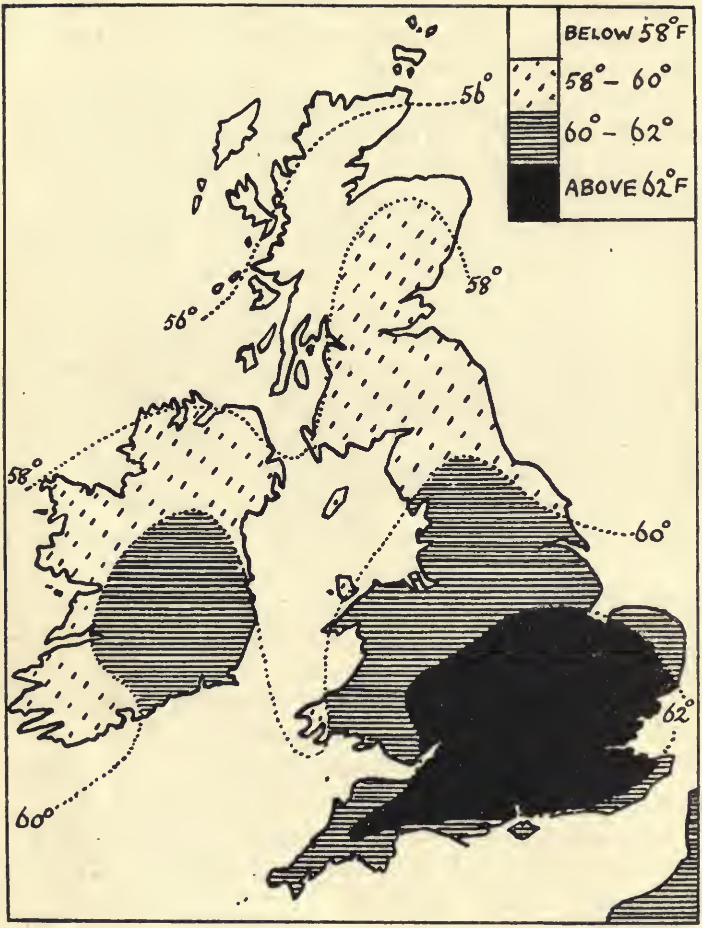


Fig. 42. July temperature.

Atacama

January Isotherms. (Fig. 43.) During January the perpendicular rays of the sun strike the earth at the Tropic of Capricorn.

When we examine a map showing January isotherms, the following are the most obvious features :—

(i) The regions of greatest heat are on the land masses where they are crossed by the Tropic of Capricorn. But the hot regions are not so extensive as the hot regions in July along the Tropic of Cancer, because the land surface of the Southern Hemisphere is small compared with that of the Northern Hemisphere. Moreover, wherever rainfall is low, we find a hot desert crossed by the Tropic of Capricorn. These are the Atacama Desert in Northern Chile, the Kalahari in South Africa, and the Victoria and Great Sandy Deserts in Western Australia.

Atacama

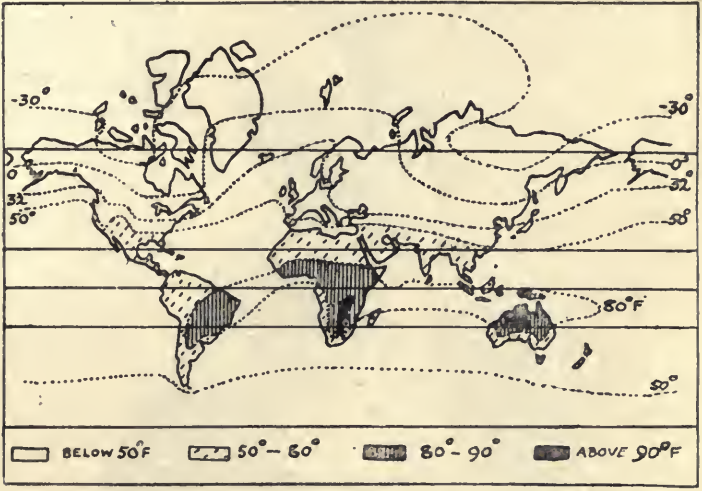


Fig. 43. January temperature.

(ii) The intermediate regions of the Atlantic, Indian, and Pacific Oceans are relatively cool.

(iii) In the Northern Hemisphere the regions of greatest cold include not only the polar region, but also two "isothermal peninsulas" of that region extending south into the New and Old Worlds. The coldest region in the world is in Siberia, near the mouth of the Lena.

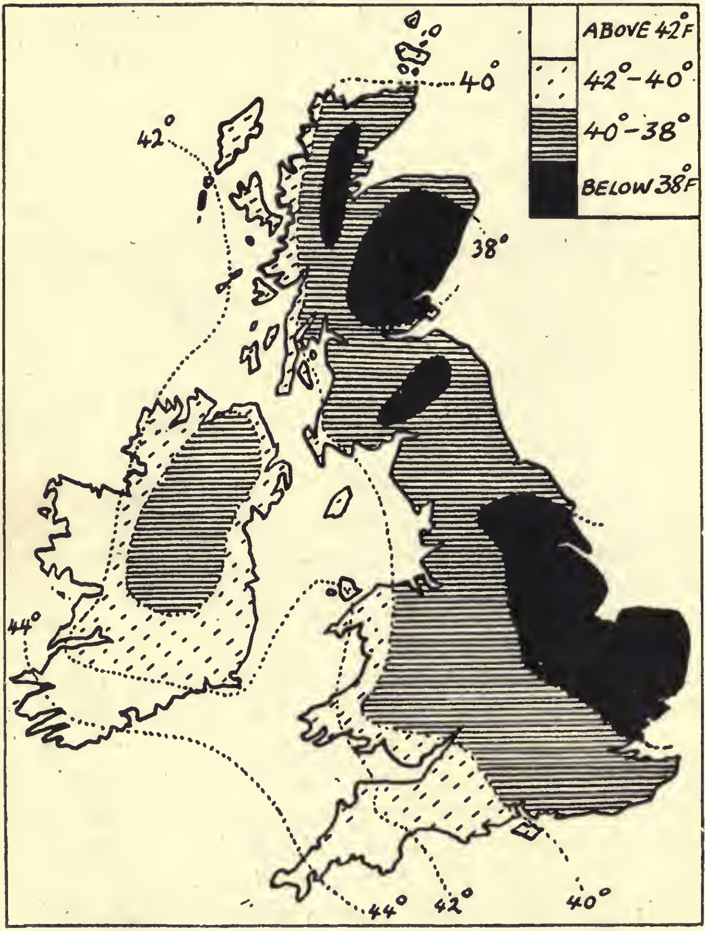


Fig. 44. January temperature.

(iv) The intermediate regions of the Atlantic and Pacific in the Northern Hemisphere are much warmer than the land areas in the same latitudes.

(v) If we follow any parallel of latitude in a cold region across a mass of land, we notice that, as we go away from the sea, the temperature becomes lower. On this account the January isotherms of the Northern Hemisphere north of the Tropic of Cancer bend southwards over the land masses and northwards over the oceans.

Examine especially the course of the 40° F. isotherm, which crosses Great Britain from Cape Wrath in the north to the Isle of Wight in the south.

Also compare the January temperatures of the above-mentioned places (**London, Berlin, Warsaw,** etc.), and examine an isotherm-map of the British Isles for January, and note that the isotherms bend south over Ireland, but north over the Irish Channel (Fig. 44).

Annual Range of Temperature. (Figs. 45 and 46.) A map on which lines of equal annual range of temperature are drawn will show the following facts:—

(i) The range of temperature is least in equatorial regions, and becomes greater the further a place is removed from the equator.

We know that at the equator the day has the same length as the night throughout the year, while, the further a place is removed from the equator, the greater will be the variation of the lengths of the day and night during the year. Consequently at the equator there will not be such a great difference between the amounts of heat received on different days during the course of the year as there will be at places further north and south.

(ii) The lines of equal annual range of temperature bend northwards over the oceans but southwards over the continents in the Northern Hemisphere. In the Southern Hemisphere they bend in opposite directions. For example, examine the region where the annual range does not exceed 5° F. Notice:—

(*a*) It is a belt around the earth approximately symmetrical about the equator, except in the Pacific Ocean, where it extends as far north as 45° N. lat.

(*b*) The zone contracts to a width of about 10° or less over S. America and Africa.

(*c*) It expands to a width of about 35° over the Atlantic, 45° over the Indian Ocean, and 70° over the Pacific Ocean.

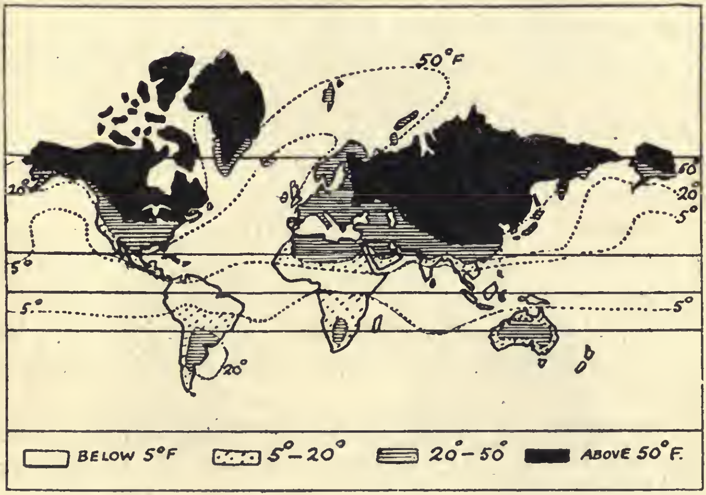


Fig. 45. Mean annual range of temperature.

(*d*) Northern extensions over the Arabian Sea and the Bay of Bengal, with intervening contractions over the peninsulas of India and S.E. Asia.

These facts show that, as a general rule, range of temperature increases with distance from the sea.

(iii) The range of temperature in the North Temperate Zone is least on the western sides of the continents and greater on their eastern shores.

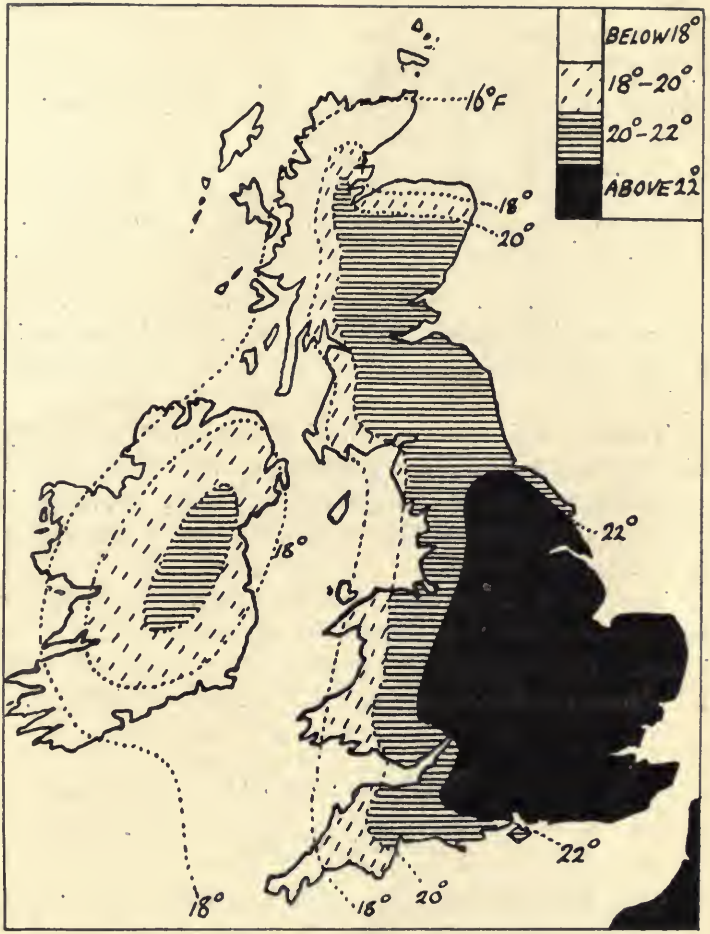


Fig. 46. Mean annual range of temperature.

This shows clearly that proximity to the sea has little influence on range of temperature, unless the prevailing winds come from the sea. As the north temperate regions of the Atlantic and Pacific Oceans are crossed by the S.W. antitrades, the western shores of the continents have a lower range of temperature than their eastern shores.

Note the following :—

Continent	Range on western shore	Range on eastern shore
Eurasia	I. of Wight 20° F.	Mth. of Amur 65° F.
N. America	Vancouver I. 30° F.	Str. of Belle Is. 50° F.

(iv) The direction of a mountain range, if the range has a sufficient height, has a considerable influence in determining the range of temperature of an inland region.

The mountains of western Europe allow the westerly winds from the Atlantic to penetrate far into the continent, and in consequence the range of temperature at **Moscow** is not more than about 55° F., though Moscow is about 1600 miles from the Atlantic.

The Rocky Mountains of western America prevent the sea breezes from carrying their tempering influence far inland. Consequently at Calgary, which is less than 500 miles from the Pacific, the range of temperature is 60° F.

CHAPTER VII

CLIMATE (WINDS)

The Barometer. A simple mercurial barometer is made by taking a glass tube about a yard long and first closing one end of it in a hot flame. Then it is completely filled with mercury and the open end closed by the thumb, while the tube is inverted and stood in a dish of mercury. When the thumb is removed the mercury will fall in the tube, leaving a vacuum above the top of the mercury column. The height of this column, measured vertically from the surface of the mercury in the dish, will be found to vary from time to time, but will rarely fall as low as 28 inches, or rise as high as 31 inches. Thirty inches is taken as the normal height of the barometer at the sea level. As a column of mercury 30 inches high standing on 1 square inch would weigh about 15 lbs., it follows that the normal pressure of the atmosphere is about 15 lbs. to the square inch.

The pressure varies with altitude. For an ascent of 3½ miles the height of the barometer is halved: when the barometer is 30 inches at sea level it will be 15 inches at an altitude of 3½ miles; and 7½ inches at a height of 7 miles, and so on.

Isobars. The distribution of pressure on the globe is shown by means of isobars.

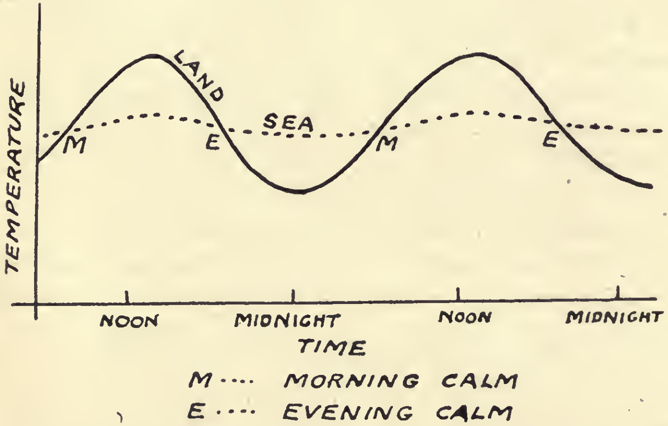
An isobar is a line joining points where pressures are equal at the same time. It must be remembered that the pressure at any place is reduced to what it would be at the sea level at the same time.

The most useful isobars are:—

1. Isobars for January, showing the mean pressure at places for the month.
2. Isobars for July.
3. Isobars showing annual mean pressure.
4. Daily isobars for details of any small region.

Winds and Pressure. Winds blow from a region of higher pressure to a region of lower pressure, and the force of the wind varies as the difference between the pressures in the two places: the greater the difference—the steeper the pressure gradient—the greater will be the velocity of the wind.

Convection Currents. Convection currents are caused in fluids by different regions on the same level being unequally dense. The fire in the grate heats the air in the chimney and causes it to expand so that, volume for volume, it becomes lighter than the cooler air in the room. Therefore the heavier air, being more strongly attracted to the earth by gravity, forces the lighter air to rise up the chimney. It must be remembered that unequal heating provides the difference of density and gravity provides the motive force by which air is moved from the denser to the less dense region.



TEMPERATURE CURVES OF LAND AND SEA

Fig. 47.

Land and Sea Breezes. In maritime regions on a clear summer day land and sea breezes are often generated.

The specific heat of land is much lower than that of water; it takes far more heat to raise the temperature of water one degree than it does an equal weight of soil. On this account, under similar conditions, land will become warm more quickly and cold more quickly than water. (Fig. 47.)

1. **Morning Calm.** (Fig. 48.) In the morning, about 8 or 9 o'clock, the temperature of the sea and of the land will be about equal to one another. Thus the air over land and sea will be equally warm and equally dense. There will be no difference of pressure, and consequently no wind.

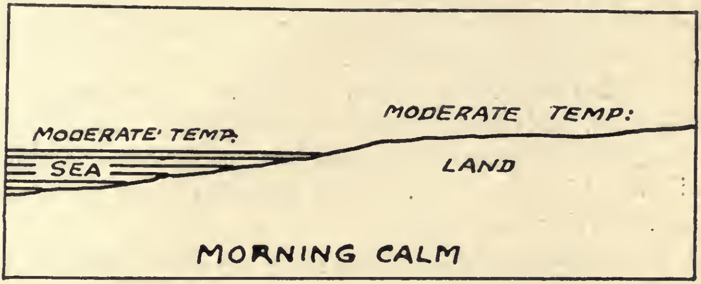


Fig. 48.

2. **Sea Breeze.** (Fig. 49.) As the sun becomes higher in the sky, the land will become warmer than the sea, though equal amounts of heat are given to land and sea, surface for surface. Thus the air over the land will become warmer and less dense than the air over the sea. This will cause a difference of pressure, the greater pressure being over the sea. In consequence, a wind will blow from the sea to the land. This wind, at first very light, will become

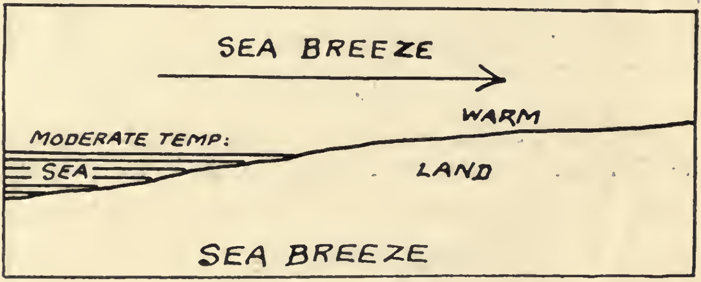


Fig. 49.

stronger and stronger until about 3 p.m. After this the declining sun will cause the surface of land and sea to gain less heat than they lose. Thus their temperatures fall. But the temperature of the land will fall more rapidly than that of the sea, so that the difference of temperature, and also the difference of pressure, will become less and less. On this account the sea breeze will become weaker and weaker during the afternoon.

3. **Evening Calm.** (Fig. 50.) When the temperature difference, and consequently the pressure difference, has disappeared, the sea breeze will have died out and the air will be still once more. This occurs in the evening at about 8 o'clock.

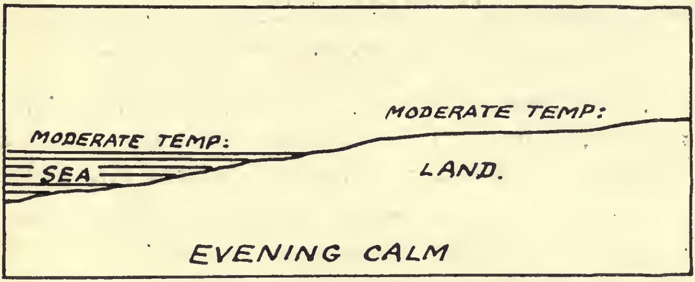


Fig. 50.

4. **Land Breeze.** (Fig. 51.) During the evening and the night the land and sea continue to fall in temperature,

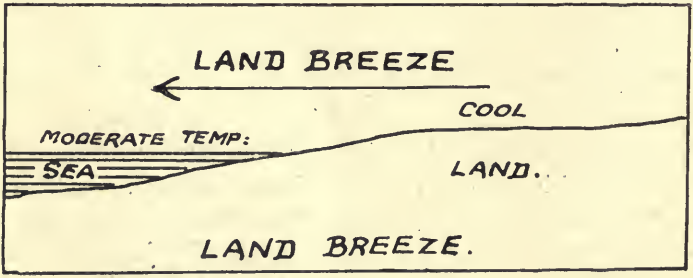


Fig. 51.

but the temperature of the land becomes lower than the temperature of the sea, and the consequent pressure difference causes the land breeze to set in. As the temperature difference increases during the night, the land breeze increases in strength, until the dawn causes the temperature of the land to rise more rapidly than that of the sea. The pressure difference is therefore decreased, and the land breeze becomes weaker and weaker until it dies away and the morning calm occurs again.

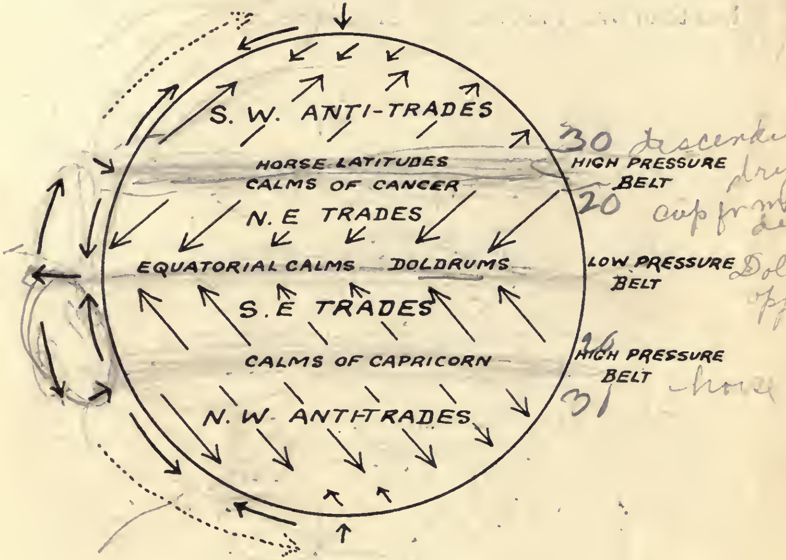


Fig. 52.

Distribution of Pressure. (Fig. 52.) The distribution of annual mean atmospheric pressure is as follows:—

1. **An Equatorial Belt of Low Pressure.** This encircles the earth approximately along the equator, but slightly to the north of it. It is caused by the high annual mean temperature of this belt.

2. **Tropical High Pressure Belts.** These high pressure regions are between 20° and 30° N. Lat. and 20° and 30° S. Lat. Various explanations have been given to account for these regions of high pressure.

3. **Low Pressure Regions of High Latitudes.** The positions of the high and low pressure regions would vary very little throughout the year if the surface of the earth were uniform in character—all land or all water—and, as a matter of fact, they vary least over the Atlantic and Pacific Oceans, and over the Southern Hemisphere they vary far less than over the Northern Hemisphere.

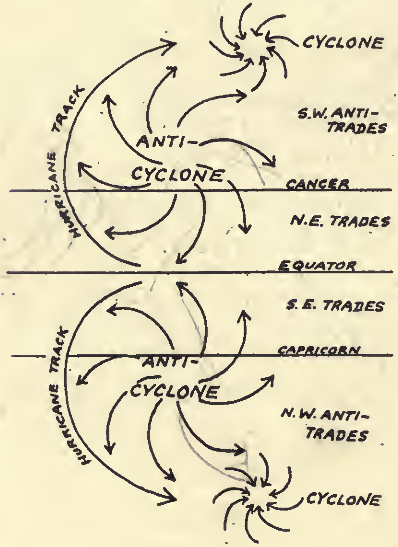


Fig. 53.

Prevailing Winds. (Figs. 52 and 53.) Neglecting for the present the seasonal changes, the following are the principal zones :—

1. **Equatorial Calms.** In this belt, which runs approximately along the equator, the air is rising vertically.

This is a belt of calms, frequent rains, and violent thunderstorms.

2. **N.E. Trades.** These are winds blowing from the tropical high pressure region southwards towards the equator. It is the rotation of the earth which makes them north-easterly.

3. **S.E. Trades.** These are winds blowing from the high pressure zone along the Tropic of Capricorn northwards towards the equator. The rotation of the earth makes these winds south-easterly.

4. **Calms of Cancer and Capricorn.** These calms coincide with the tropical high pressure regions. They are regions of fine weather.

5. **S.W. Antitrades.** These winds blow from the high pressure region along the Tropic of Cancer towards the north, but the earth's rotation turns them into south-west winds.

6. **N.W. Antitrades.** These winds blow towards the south away from the Tropic of Capricorn. South of Lat. 40° S. they become more and more westerly, and are known as the Roaring Forties or Brave West Winds.

The above mentioned belts are rather to be taken to represent the state of affairs which would obtain if the surface of the earth were uniform in character and if seasonal changes were absent.

This relatively simple distribution is interfered with in several ways :—

1. **Distribution of Land and Water.** In the Southern Hemisphere, where the land masses are comparatively small, there is relatively little variation in pressure throughout the year and the winds maintain a fairly constant direction. Thus we find the belts mentioned above fairly well represented. There is however a considerable variation over Australia and, to a less extent, over S. Africa and S. America.

But in the Northern Hemisphere the land masses are very large. The temperate region of Eurasia extends nearly half-way round the world, and N. America is about 3000 miles wide from east to west. These land surfaces are hot in summer and very cold in winter, while the intervening N. Atlantic and N. Pacific retain an even temperature. On this account, while the pressure over the oceans will not undergo very great variation, the pressures over the land will vary greatly during the year. In summer the land surface will be hot and the atmosphere above it will be at a low pressure, causing winds to blow towards the land mass, while in winter they will be high pressure regions, with winds blowing outwards.

2. **Seasonal Changes.** The seasonal changes will not only help to cause the modifications referred to in the last paragraph, but they will also cause an annual movement north and south of all the great belts. Thus the equatorial calms are to the north of the equator in July and practically on the equator in January, and so with the other belts.

3. **Rotation of the Earth.** The rotation of the earth from west to east tends to make all winds set themselves in an E. to W. direction. This influence is felt most by winds which, except for rotation, would blow along a meridian. Thus the winds which are deflected most are the trades blowing towards the equator and the antitrades blowing towards the poles. For example, the trade winds blow towards a region where the W. to E. velocity is greater. Thus they "lag behind" and become north-easterly instead of being northerly winds. Or it may be put in another way :—The earth's rotation tends to give winds blowing towards the equator an easterly direction (i.e. blowing from E. to W.). This motion compounded with the N. to S. motion gives to the wind a north-easterly resultant.

Again the antitrades, blowing from the Tropic of Cancer towards the North Pole, blow towards a region where the W. to E. velocity is less, and consequently "get ahead" and become south-westerly instead of being southerly winds. Or we may consider the matter thus :—The earth's rotation tends to give winds blowing away from the equator a westerly direction (blowing from W. to E.). This motion and the S. to N. motion together give a south-westerly resultant.

Similarly the deflection of winds in the Southern Hemisphere can be explained.

The various facts are expressed in a generalisation known as **Ferrel's Law** :—

In the Northern Hemisphere winds are deflected in a clockwise manner, while in the Southern Hemisphere they are deflected in a counter-clockwise manner. (Fig. 53.)

Anticyclones. Winds will blow outwards from a region of high pressure towards the surrounding regions of lower pressure. If the earth were still they would blow *radially* away from the high pressure region. But the rotation of the earth causes these winds to undergo deflection according to Ferrel's Law. Consequently they blow spirally away from the high pressure region. Moreover the spiral is a "close" one so that the winds cross the isobars, making a very small angle with them.

The isobars in an anticyclone are approximately circular or elliptical, and the pressure is higher on the side of the isobar towards the centre of the anticyclone.

They are generally fine weather regions—hot and dry in summer, bright and cold in winter—for reasons which we shall understand later on.

Cyclones. Where there is a low pressure region, the winds will tend to blow radially towards it from the surrounding high pressure regions, but according to Ferrel's Law they are deflected and blow spirally towards the low pressure centre. The spiral is a close one. The isobars are approximately circular or elliptical, and the pressure is higher on the side of the isobar more remote from the centre of the cyclone.

Disturbances are relatively small cyclones which follow well defined tracks. They may be looked upon as atmospheric eddies which follow a path around the outskirts of anticyclones. Thus in the North Atlantic disturbances originating in equatorial regions are carried west to the West Indies, then along the eastern coasts of N. America and across the Atlantic to N.W. Europe. This accounts for the fact that most of our bad weather comes from the W. and S.W. Moreover, these wet cyclones make our winter climate mild and our summer climate cool.

Distribution of Pressure in July. (Fig. 54.) During July an anticyclone covers the N. Atlantic between 10° N. and 60° N. and extends from the Mississippi on the west to Central Europe on the east. A similar anticyclone covers the N. Pacific in the same latitude. At the same time over the heated surface of Asia is an immense cyclone with its centre in Baluchistan. A much smaller though similar cyclone is situated over the heated highland region in the west of the United States.

Remembering that in the Northern Hemisphere the air moves clockwise in anticyclones and counter-clockwise in cyclones, we observe :—

1. The N.E. trade winds are the winds of the southern parts of the anticyclones.
2. The S.W. antitrades are the winds of the northern parts of the anticyclones.
3. The S.W. Monsoons of S.E. Asia are winds blowing into the Asiatic cyclone from the Indian and Pacific Oceans.
4. Storm tracts follow the outskirts of the N. Atlantic

and N. Pacific anticyclones. The cyclones are usually most violent in the tropical part of their course, and are much weaker by the time they are travelling along the northern border of the anticyclone. Thus the West Indies and S. E. States of America suffer from violent storms far more frequently than we do in W. Europe.

Turning to the Southern Hemisphere, we notice an almost continuous belt of high pressure along the Tropic of Capricorn, but within this belt are three regions of higher pressure, which form anticyclones in the S.E. Pacific region, the S. Atlantic and S. Indian Oceans.

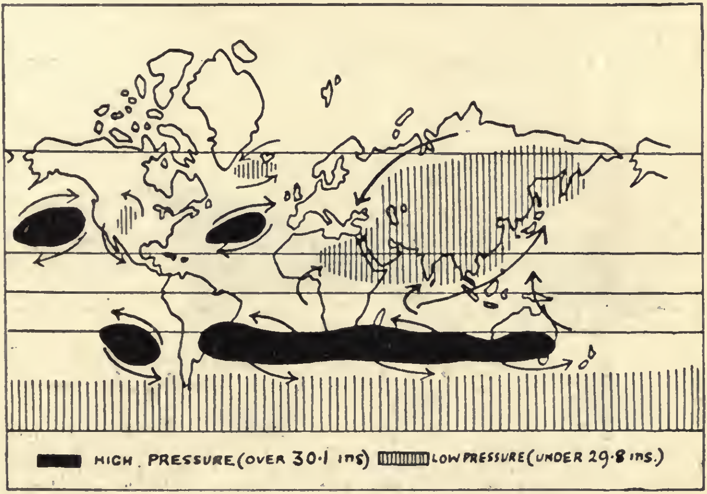

HIGH . PRESSURE (OVER 30·1 ins)
LOW PRESSURE (UNDER 29·8 ins.)

Fig. 54. Pressure and winds in July.

In the Southern Hemisphere the air moves in a counter-clockwise manner in anticyclones; consequently we observe:—

1. The S.E. trade winds are the winds of the northern parts of the anticyclones.

2. The N.W. antitrades and brave west winds are the winds of the southern parts of the anticyclones.

Distribution of Pressure in January. (Fig. 55.) During January the high pressure belt along the Tropic of Cancer is far more complete than in July. Within it, and extending far north, are two high pressure regions—one being over the cold surface of Eurasia, the other over the cold surface of N. America. Between these are two cyclones. In the N. Atlantic, extending from about 50° to 70° N. lat., is a cyclone with its centre between Iceland and Greenland. In the N. Pacific a cyclone extends from about 35° N. to the Behring Sea. We notice :—

1. The N.E. trades blow in the southern parts of the anticyclones.

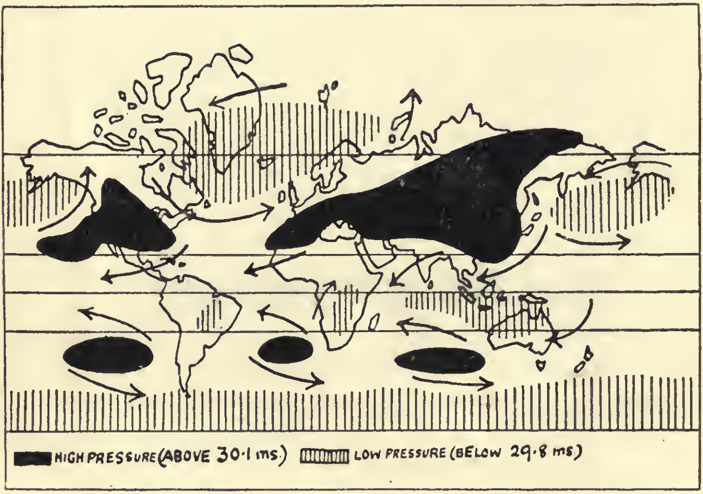

▬ HIGH PRESSURE (ABOVE 30·1 ins.)
▥ LOW PRESSURE (BELOW 29·8 ins)

Fig. 55. Pressure and winds in January.

2. The S.W. antitrades blow in the southern part of the cyclones.

3. The N.E. monsoons of S. and E. Asia are obviously the trade winds, strengthened by the excessive pressure in the Eurasian anticyclone.

Turning to the Southern Hemisphere, we observe that the belt of high pressure is approximately in the same latitude as before, but the three anticyclones within it are far more clearly separated than in July. This is accounted for by the fact that heated regions of S. America, S. Africa and Australia form low pressure areas over which cyclones are formed. The cyclone over the N.W. of Australia is far more pronounced than those over S. Africa and S. America.

We observe the positions of the trades and antitrades as before, and we also note the storm tracks skirting the anticyclones of the S. Atlantic and Indian Oceans. We can now understand that while the eastern shores of the continents are often visited by disastrous storms the western coasts are almost free from them.

Monsoons. We have already mentioned these winds. They are "season" winds and are found in many districts, but are nowhere so pronounced and so important as in the S. and E. of Asia.

During summer the centre of Asia will be very hot and the expansion of the air will cause a low pressure in that region. Hence there will be a draught of air from the surrounding regions towards the centre of Asia. According to Ferrel's Law the winds will be deflected in a clockwise manner. Thus the prevailing winds in summer over the S. and S.E. of Asia will be south-westerly. Over E. China and Japan they are southerly.

During winter the centre of Asia is exceedingly cold, and hence the air will be dense and the pressure high. Consequently winds will blow outwards. These winds deflected according to Ferrel's Law will become N.E. over S. and S.E. Asia, while over China and Japan they are more northerly.

It is clear that monsoons are really land and sea breezes on a grand scale, where the summer may be looked upon as a long day and the winter as a long night.

Monsoon winds also blow in the N. Australian region, where the temperature varies far more widely over the continent than over the surrounding oceans.

A somewhat similar monsoon region is found in Lower California, in N.W. Mexico, and along the western coast of Mexico.

Local Winds.

1. **Etesian Winds** blow over the Mediterranean towards Africa in summer during the heat of the day, when the Sahara Desert is very hot.

2. **Cold Winds from Central Europe to Mediterranean.** These are called the **Mistral** in S. France, **Bise** in Switzerland, **Bora** in the Karst region of Austria, and **Gregale** in Malta.

3. **Hot Winds.** When a region of low pressure is formed on the outskirts of a hot region, hot winds are caused. These are called **Simoom** in Arabia, **Khamsin** in Egypt, **Sirocco** in Sicily, and **Solano** in Spain.

4. **Föhn** is a warm wind from the south over the mountains. It is dry and warm and rapidly melts the snow. It is often explained by supposing that the draught of air coming from a higher to a lower region is heated by compression. Another explanation supposes it to be a warm wind from the Sahara.

5. **Chinook.** This warm wind from the Rockies probably acquires its heat by compression as it descends to the plains.

6. **Dry East Winds in England in Spring.** As the Northern Hemisphere increases in warmth a draught of wind sets in from the poles. This becomes easterly or north-easterly on account of the rotation of the earth. The above is the explanation usually given for our dry cold spring east winds.

CHAPTER VIII

CLIMATE (RAINFALL)

Evaporation. The free surfaces of all bodies of water are continually giving off water vapour. In fact, even ice below freezing point gives off water vapour.

It can be shown by a few simple experiments that the conditions which favour evaporation are the following :—

(i) A high temperature.

(ii) A low pressure.

(iii) A dry atmosphere.

(iv) Wind.

(v) Extent of evaporating surface. The total amount of evaporation varies directly as the area of the evaporating surface.

It is also necessary to remember that, when a liquid evaporates, heat is rendered latent, that is, it no longer affects temperature. Consequently, where evaporation is taking place, heat will apparently disappear, and the temperature of the surface of the water and of the air will be lowered.

In equatorial regions the temperature of the sea will be high and evaporation rapid. But the air is rising vertically and, as it cools, the vapour in it will condense and torrential rains occur. In this way a large proportion of the water is returned almost immediately to the surface from which it had evaporated, and consequently equatorial waters are not the most saline regions of the open seas.

The Red Sea presents different conditions. It has a high temperature, but being between hot deserts the air above it will be hot and dry. Thus, while evaporation is great, there is practically no rainfall and the waters of the Red Sea are very saline.

The Mediterranean is a very similar region and also possesses very dense saline water.

In the open ocean we find that the densest sea water is found in those parts over which the great anticyclones are situated. In these regions cool dry air is descending vertically in the centre of greatest pressure, and from this centre the dry air will blow spirally outwards. This dry air will cause abundant moisture to evaporate from the surface of the ocean, and, as the winds continually blow away from this region, the rainfall will be very light, and consequently very little rain will fall in those regions of high pressure from which the water has evaporated.

In the southern parts of the anticyclones of the Northern Hemisphere the winds (N.E. trades) blow from a cool to a warmer region; consequently these are dry winds until they are driven upwards over high land, or until they begin to rise vertically in equatorial regions. When it is said that they are "dry" we mean that the moisture they contain does not nearly saturate them. As a matter of fact they contain an enormous quantity of invisible moisture.

The antitrades blow from a warmer to a cooler region. On this account the air as it moves towards the north is able to contain a smaller and smaller amount of moisture. Thus the air becomes more and more saturated with moisture. These winds are wet winds and they return a considerable amount of water to the ocean. Moreover in these colder regions evaporation will be less rapid, both on account of the lower temperature and on account of the air above the ocean being already moist. On this account the waters on the polar sides of the great anticyclones are much less dense, the density on an average decreasing towards the poles.

The colder inland seas, such as the North Sea, possess much fresher water than the open sea, partly on account of the amount of river water flowing into them, partly upon the small amount of evaporation, but also in a large measure upon the fact that ocean currents do not disturb the seas and mix denser open sea water with the fresher water.

The evaporation taking place from the surfaces of cold ocean currents is relatively slight, and on this account we find the cold Arctic drift lowers the salinity of the sea along the east coast of N. America as far south as Cape Hatteras. On the other hand, warm drift currents not only increase evaporation, but also come from a region where the sea water is dense. Thus we find that the density of the sea water near Spitzbergen is as high as the density of the sea water off Cape Hatteras, though the former place is 45° further north than the latter.

Inland seas in very hot regions often lose by evaporation more water than rivers bring to them. It can easily be understood that, provided the conditions do not vary, such an inland sea will shrink until the total amount of water evaporated just counterbalances the inflow from the rivers. Many inland seas are comparatively small relics of former larger inland seas. The great salt lake of Utah is such a one. Such lakes have no outlet to the open sea.

Condensation. It is necessary to keep in mind the following facts :—

1. When water vapour loses sufficient heat, it is condensed.

2. When water vapour condenses, the latent heat is rendered sensible and raises the temperature of the moist air. In this way the temperature of the air is prevented from falling as low as it would if no condensation occurred. Thus we might say that condensation is opposed to condensation. On this account we find that in winter the temperature is higher during damp rainy weather—the latent heat liberated causing a higher temperature in the air.

3. In order that condensation may occur, dust particles must be present in the moist air. Minute dust particles are

always present in the air but the amount of dust decreases with the height above sea level. Thus, on an average, very high regions are much drier than lower regions, provided, of course, other conditions are similar.

4. When air expands, it loses heat and its temperature falls. If the temperature falls sufficiently, the moisture in the air may be condensed. Thus we might say that expansion of the air would cause condensation, but to counterbalance this, there is the fact that the lowering of pressure in expansion increases evaporation; again, the lowering of temperature due to expansion is partly counterbalanced by the rising of temperature during condensation.

5. When air is compressed, its temperature rises. This in its turn helps to prevent condensation which would otherwise occur.

It will therefore be evident that the condensation in the atmosphere will depend on many conditions, the actions of which are so complex that it seems almost hopeless to attempt to apply them to explain condensation in the atmosphere. But there are a few simple facts which assist us.

1. **Absolute Humidity of the Air** is the amount of invisible water vapour which a definite volume of the air holds. This varies in different regions, and in the same region from time to time.

2. **Air saturated with Moisture.** At any particular pressure and at any particular temperature a certain definite volume of air is able to hold a certain definite amount of invisible water vapour. When it holds that amount of water vapour it is said to be saturated at that temperature and pressure.

3. **Relative Humidity of the Air** is the amount of water vapour it contains compared with the amount of water vapour it would contain if saturated under the same conditions of temperature and pressure.

4. When the temperature of air containing water vapour is lowered, its *relative* humidity is increased—it becomes "wetter."

5. When the temperature of air containing water vapour is raised, its *relative* humidity is decreased—it becomes "drier."

The change of temperature does not affect the absolute humidity, provided condensation does not occur.

6. When the temperature of air saturated with water vapour is lowered, a portion of the water condenses to form drops of water. The greater the lowering of temperature, the greater will be the amount of water condensed.

7. When the temperature of air saturated with water vapour is raised, its relative humidity decreases and the air becomes unsaturated.

Clouds, Mist, Fog. The collections of water drops formed by condensation are known as **cloud**, if elevated above the earth's surface; but if the cloud forms on the surface, it is known as mist or fog. In a **mist** the water drops are large: one becomes very wet in a mist. In a **fog** the particles of water are smaller and the fog does not wet one so readily as a mist does. Fogs in towns often contain large quantities of dust—hence their dirty yellow, brown or black colour.

Dew. When solid bodies lose heat at night by radiation, they sometimes become so cold that the layer of air in contact with them becomes lowered in temperature so that it is reduced to saturation point, and then, on the slightest further reduction in temperature, drops of dew are condensed out of the atmosphere upon the cold surface of the solid. The temperature at which dew commences to form is known as the dew point. It can be found by dipping a thermometer in a little ether in a test-tube and blowing air through the ether from a bellows. Note the temperature at which dew appears on the outside of the test-tube. The greater the amount of moisture in the air in contact with the earth, the higher will be the dew point.

The formation of dew is favoured by the following conditions :—

1. Clear sky allows the surface of the earth to lose heat rapidly by radiation.

2. Much wind prevents dew forming, as new layers of air above the saturation temperature are constantly brought over the cold surface of the earth. A gentle breeze, however, assists the formation.

3. On a warm sunny day the earth becomes warmed to a considerable depth. At night the lower layers of soil remain warm and give up vapour which, rising into the air, is condensed as dew on the cold objects at the surface.

A warm day also causes water to evaporate into the air, and at night the atmosphere charged with moisture is reduced to its saturation temperature, and the evaporation of the deposited dew is prevented.

The deposition of dew in hot countries, where the rainfall is light, is of great importance. Though the air is relatively dry in such places, yet the absolute humidity of the air may be high. Consequently the temperature has not to fall so low as we might at first suppose. Moreover, the clear sky allows the earth to lose heat rapidly by radiation.

If the temperature of the surface on which the moisture is condensed is below freezing point, hoar frost will be formed—a collection of ice crystals instead of water drops.

Rainfall. Rainfall is measured by means of a rain-gauge. A rain-gauge consists of a funnel, the stem of which allows the rain to run into a measuring vessel.

If all the rain which fell remained on the surface where it fell and none of it either ran off the surface, soaked into the earth, or evaporated, then the earth would be covered with a layer of rain water which would vary in depth from place to place. In some regions, such as Assam, the year's rain would cover the earth to a depth of over 40 feet, while on some of the deserts the depth would be practically nil.

The diameter of the funnel is usually either 5 or 8 inches. Suppose the diameter of the measuring cylinder to be 1 inch. It follows that $\frac{1}{2}$ inch of rain falling into the 5 inch funnel will fill the measure to a height of $\frac{25}{2}$ inches or 12·5 inches. Thus the $\frac{1}{100}$ inch divisions will be $\frac{1}{4}$ inch on the measure and can be more accurately read. If a cylindrical can were used in place of the funnel and measure glass, not only would the hundredths of an inch be almost impossible to measure but much of the rain might evaporate and not be measured at all.

The readings are usually taken daily and the most useful records are:—

1. **Mean Monthly Rainfall.** This is the average of the rainfalls of a particular month taken over a certain number of consecutive years.

2. **Mean Annual Rainfall.** This is the average of the rainfalls of a certain number of consecutive years. It is useful to remember that one inch of rain gives about 101 tons of water per acre, and that 10 inches of snow are equivalent to about 1 inch of rain.

Distribution of Rainfall. (Fig. 56.) We have already seen that clouds form when the air laden with moisture is cooled below the temperature of saturation. This is brought about in many ways, of which the chief are the following:—

1. **Air rising vertically.** This happens in the equatorial belt. The air is rising not only to a colder region of the atmosphere, but it is also expanding, and this increases the rate of cooling. Consequently in this region torrential rains occur almost daily throughout the year. Near the equator some regions possess two wet and two dry, or

rather two less wet, seasons, the wet seasons occurring when the sun is overhead.

2. **Air forced over Highlands.** This is perhaps the principal cause of rainfall. When the moisture-laden wind blows over the land the air is compelled to rise over highlands. This causes rainfall, which will be more or less heavy according as the air is more or less moist, and also according to the height of the mountains. Mountains are condensers because they compel the vapour laden air to rise to higher and colder levels. The expansion consequent on reduced pressure also helps to bring about condensation.

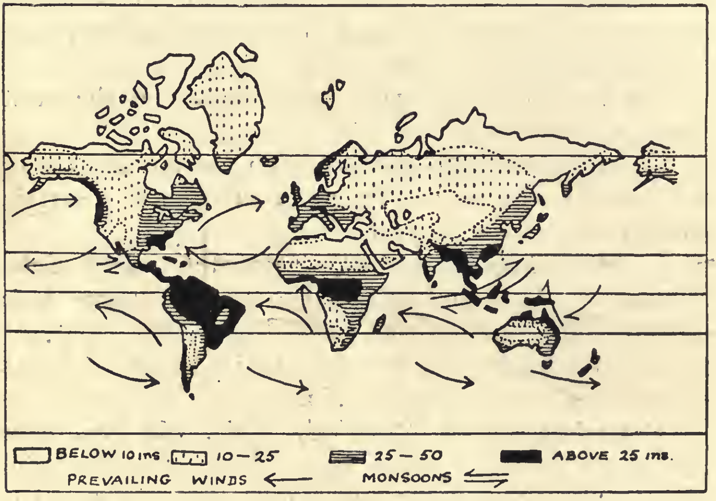


Fig. 56. Mean annual rainfall.

On examining a rainfall map (Figs. 56 and 57), we notice that the regions of heaviest rainfall are highland regions which are in the tracks of prevailing moist winds. The trade winds give an ample rainfall to the eastern side of that part of America toward which they blow, while the antitrades bring rain to the coasts of the western side of the continent further north and further south. The

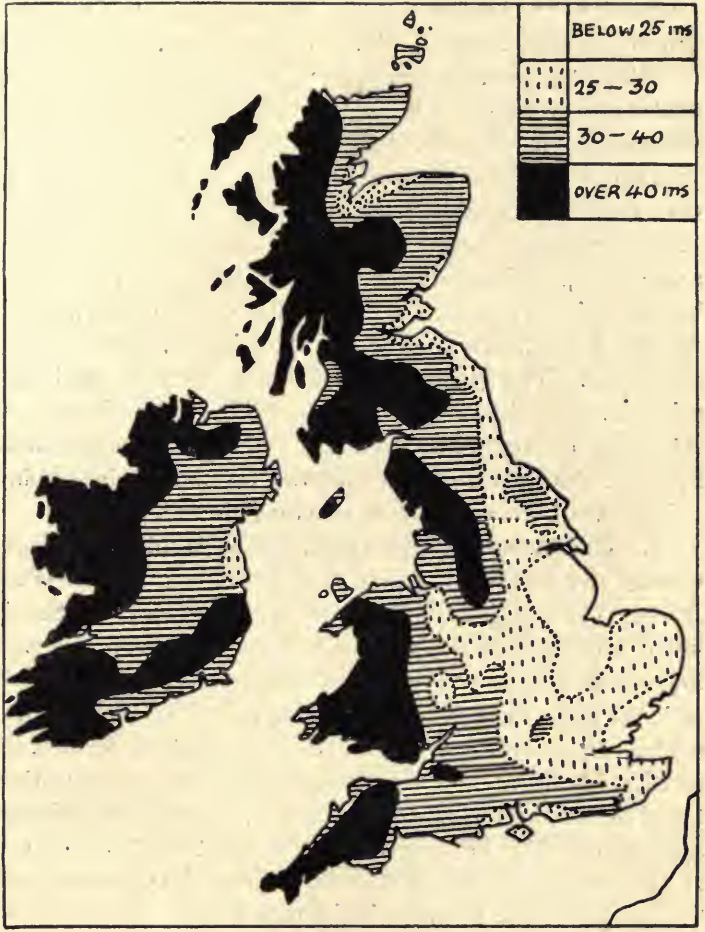


Fig. 57. Mean annual rainfall.

highlands of the British Isles, the highlands of West Africa, the Western Ghauts and Himalayas of India, and the mountains of Assam are in the track of moist winds bringing abundant rainfall to those regions.

When the mountains are at right angles to the direction of the prevailing moist wind, the rainfall is heaviest, and if the mountains are sufficiently high, the side away from the prevailing wind will receive a very light rainfall. Not only does elevation cause the condensation of a large proportion of the water vapour, but, as the air descends on the other slope, compression raises its temperature, and its relative humidity is decreased. Thus Thibet is in the rain shadow of the Himalayas during the blowing of the summer monsoons. The great plains of North America are in the rain shadow of the Rocky Mountains. The deserts of Atacama, Kalahari, and, to a less extent, the eastern slope of Great Britain are in rain shadows, the moist winds being driven over highlands before reaching these regions.

3. **Condensation prevented by a Heated Surface.** One of the best instances of this is found in North-West India. Here the S.W. monsoon from the Arabian Sea is laden with abundant moisture, but while passing over the lower and middle valley of the Indus and the region east of it the great heat of the level plain raises the temperature of the air far above its saturation temperature, so that its relative humidity is low. Consequently no condensation takes place until the vapour-laden air is compelled to rise on approaching the Himalayas. Here, on the slopes of the Himalayas, the greater part of the moisture is condensed and the fertility of the Punjaub is the result.

4. **Rainfall in a Cyclone.** The small cyclones known as disturbances rotate in a counter-clockwise manner in the N. Hemisphere, and concerning them we note the following facts :—

(*a*) The lowest pressure is in the centre of the cyclone.

(*b*) Winds blow spirally towards the centre from surrounding regions.

(*c*) The eastern side of the cyclone is the rainier side, because not only is the air cooled by expansion but it is moving northwards, from a warmer to a colder region.

(*d*) The air in a cyclone is rising, and hence becoming cooler. This causes condensation to occur in the cyclone generally, so that a cyclonic system is a rainy system.

(*e*) The isobars are often very close to one another, the pressure gradient is steep, and therefore the wind is often high, sometimes reaching a gale.

(*f*) These cyclones usually come into our region from the west or south-west. Consequently, as they pass over our region, the weather will change in a definite manner which can be foretold with considerable accuracy. For example, if the southern part of a cyclone passes over a particular district, the wind will be S.W. at first and rain will fall. Then the wind will veer to the west, and though rain will fall there will be fine intervals. Still later the wind will veer N.W. and it will become finer and colder.

(*g*) Where the configuration of the land causes winds to converge, the air will rise and become cooled. Consequently rain may be expected in such places.

5. **Anticyclone.**

(*a*) An anticyclone usually covers a greater area than a cyclone does.

(*b*) The isobars are wider apart, and consequently the pressure gradient smaller, than in a cyclone. The wind is often no more than a gentle breeze.

(*c*) The centre is the region of greatest pressure, and the winds blow spirally outwards.

(*d*) The heavy air is falling and becoming warmer, so that condensation does not occur. Hence anticyclonic weather is fair weather—hot and dry in summer, cold and dry in winter. Under the clear sky dew is abundant in summer and hoar frost in winter.

6. **Seasonal Distribution of Rainfall.** (Figs. 58 and 59.) We have already noted the march of the perpendicular rays of the sun between the tropics during the year, and have seen how, in consequence, the belts of high and low pressure move north and south, making a to and fro annual journey.

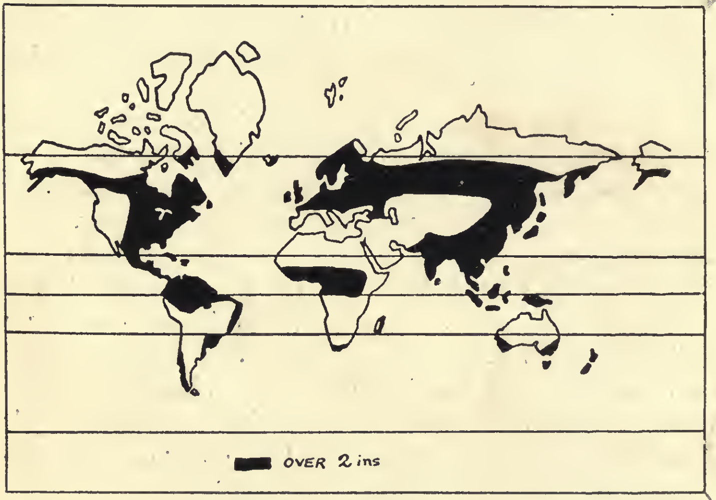


Fig. 58. Rainfall in July.

The trade winds blowing from a colder to a warmer region are dry winds, and can take up enormous quantities of moisture. When they reach the shores of the continents, or when they reach equatorial regions and rise, condensation occurs.

In equatorial regions rain falls all the year round. These regions of calms, violent storms, and torrential rains are known as the doldrums. They are practically on the equator in January and a few degrees north in July.

Further north and south, in regions over which the trade wind zones move, the greatest amount of precipitation occurs in summer.

The belts of high pressure are relatively dry. Being situated near the tropics, they are known as the Calms of Cancer and Capricorn, and the latitudes in which they are found are often called the "Horse Latitudes."

Certain regions in higher latitudes come under the influence of these belts during the summer. Such regions (Mediterranean countries, California, Argentine, South Africa, and Southern Australia) have dry summers.

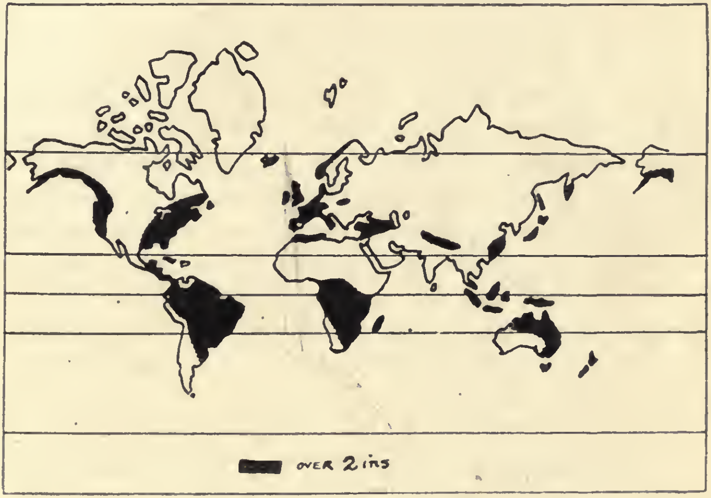


Fig. 59. Rainfall in January.

In still higher latitudes the prevailing winds are the antitrades, which, blowing from a warmer to a colder region, are moist winds. As their general direction is towards the east, they give abundant rain to the western shores of the continents on which they strike. Countries which are always within this antitrade zone receive a rainfall which is fairly evenly distributed throughout the year. The countries of N.W. Europe, British Columbia, Southern Chile, Tasmania, and New Zealand are examples.

Like the other belts, the antitrade zone makes an annual north and south journey. It follows that some regions which are within the high-pressure belts in summer are under the influence of the antitrades in winter, and will consequently receive a winter rainfall. We have already seen that the summer will be dry in these "Mediterranean" regions. The climate characteristic of such regions is often called the "Mediterranean type" of climate.

Certain land masses situated at some distance from the equator vary very greatly in temperature during the year. During their summers they are covered by a cyclonic circulation, while in winter the circulation is reversed, becoming anticyclonic. It is clear that such regions will possess well-defined wet and dry seasons, and that they will receive rain during their summers. The large land mass of Asia and its distance from the equator make it the most noteworthy example among monsoon regions. Other regions are Northern Australia and Mexico, with the adjacent regions to the north.

The chief climatic belts may be thus classified:—

(*a*) **Equatorial Belt.** This is a hot wet belt with rain throughout the year. There are two wet and two less wet seasons.

(*b*) **Trade wind Belts.** The eastern coasts facing these winds receive abundant rain, the greater amount of precipitation occurring during summer. As these winds blow over the continents they become dry, so that western coasts in these belts are dry. The great deserts of the world are situated in these belts.

(*c*) **Horse Latitudes: High-Pressure Belts.** These are relatively dry regions.

(*d*) **Mediterranean Belts** are situated along the margins of the Horse Latitudes and the Antitrades. They possess dry summers and fairly wet winters.

(*e*) **Antitrade Belts.** In these belts the western coasts facing the winds are rainy throughout the year.

(*f*) **Monsoon Regions** possess well-defined wet summers and dry winters.

CHAPTER IX

DISTRIBUTION OF VEGETATION

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What plants need.

1. **Food.** Food is obtained partly from the soil, but by far the greatest amount comes from the atmosphere. In fact all the **carbon**, which makes up about half the total weight of the dried green plant, comes from the carbon dioxide of the air.

The mineral food which is absorbed by the roots is small in amount, making up 5 per cent. or less of the dried plant. This mineral food is obtained from the soil water which dissolves minerals out of the rocks through which it soaks.

Except on very steep slopes or over very hard rocks from which the soil is washed as soon as formed, there are very few places in the world where the soil contains insufficient mineral food.

Moreover, the composition of the atmosphere is practically uniform, at least as regards the proportions of oxygen, nitrogen, and carbon dioxide, so that in every region there is an adequate supply of carbon dioxide and oxygen for the use of plant life.

It is true that the composition of the soil affects the distribution of plants to a certain extent. Thus the beech, clematis, guelder rose, bee orchis, etc. flourish best on a chalky soil, and many seaside plants are able to tolerate a relatively large proportion of salt in the soil. But the varying compositions of soils are of minor importance in controlling the distribution of widely different types of vegetation, such as prairie lands and dripping tropical forests, for the differences between soils is slight in comparison with the variations which we find in the factors we are about to consider.

2. **Moisture.** Moisture is essential to plant life in many ways. Food can be absorbed only when dissolved in water. Water also distends the cells and assists in giving firmness to the tissues. The current of sap which passes up through the veins is a means by which food absorbed from the soil reaches the leaves. A current in an opposite direction distributes elaborated food to the regions of growth and storage. Moreover water is also used in many of the chemical changes which take place : the two most important of these are the formation of carbohydrate in green cells, and the storage and digestion of reserve foods.

We have seen that the amount of moisture in the air is very variable, and consequently we can see that plants must be suitably organised in order that the amount of water vapour evaporating from the leaves shall not be so great as to render the water absorbed by the root inadequate.

We also know that the amount of rainfall is not uniform over all the world : therefore the amount of moisture available for absorption by roots will vary widely in different places. In some places the soil will be so dry that the plant must reduce loss of water to a minimum. In other places the soil will be so moist and the air so vapour-laden that the plant will have difficulty in giving off sufficient water vapour to cause a current of sap to flow upwards from the roots.

If we examine a map showing the zones of vegetation, and compare it with a rainfall map, we find that in any particular belt in which the temperature is practically uniform, such as the belt between the north and south limits of the palm, there is not a uniformity of vegetation. In the belt just mentioned we find dripping forests, open forests, grass lands, and deserts, and when we compare the map with a rainfall map, we at once see that, given sufficient food and a sufficiently high temperature, the luxuriance of the vegetation depends upon the amount of rainfall.

3. **Heat.** Heat is essential to all living things. Warm-blooded animals are in a measure independent of the temperature of their surroundings, as the chemical action in their bodies is sufficiently rapid to provide them with an adequate supply of heat. But though cold-blooded animals and plants produce heat to a certain extent from chemical action in their bodies, yet, compared with their size, the amount so produced is quite inadequate to keep their temperature more than a degree or two above that of their surroundings.

The varied living processes of plants can be carried on only between certain limits of temperature. These limits differ widely in different species of plants. On this account the distribution of plants is determined not only by rainfall, but also by the temperature of a region, and we find, as we might well expect, that the northern and southern limits of the distribution of various plants are lines more or less parallel to the equator.

Thus the plants are arranged in zones or belts of vegetation, which surround the globe approximately along the parallels of latitude (Fig. 61).

On mountains similar series of zones are found. Thus on the Abyssinian Mountains we find a succession of zones, ranging from the tropical forests of the valley floors to the " Arctic " plants of the mountain tops. All mountains show a series which is more or less extensive, the extent varying according to the altitude of the mountain and the latitude in which it is situated (Fig. 60).

The main facts are the following :—

(*a*) Plants are arranged in zones of vegetation, which are roughly parallel to the equator. This arrangement depends on temperature, which, in its turn, is dependent principally on latitude.

(*b*) In any zone of vegetation the distribution in that zone depends on rainfall.

(*c*) Elevation has much the same effect as distance from the equator.

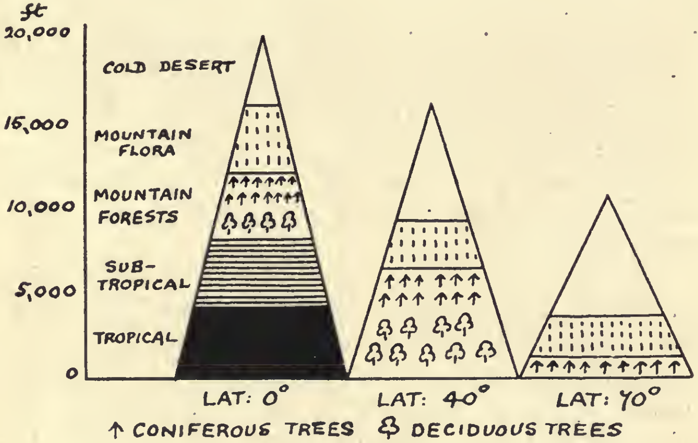


Fig. 60. Vertical distribution of vegetation.

Chief Types of Vegetation (Fig. 61).

1. **Cold Deserts.** These suffer from lack of heat, not lack of moisture: in fact, moisture may be relatively abundant, in which case the surface becomes covered with snowfields and glaciers. Such regions are found near the poles and on the tops of mountains.

2. **Tundra.** On the fringe of the Arctic deserts the warmth of the long summer days causes the surface to

thaw for a few weeks. In such places mosses and lichens are found, while still further from the pole a few bulbous plants survive. Further from the pole the heat of summer thaws the surface, and such parts as are drained become covered with a carpet of small flowering plants, which grow quickly and ripen their seed before winter returns. During such a short summer the variously coloured flowers all open at the same time, and the tundra flora, though short-lived, is exceedingly beautiful.

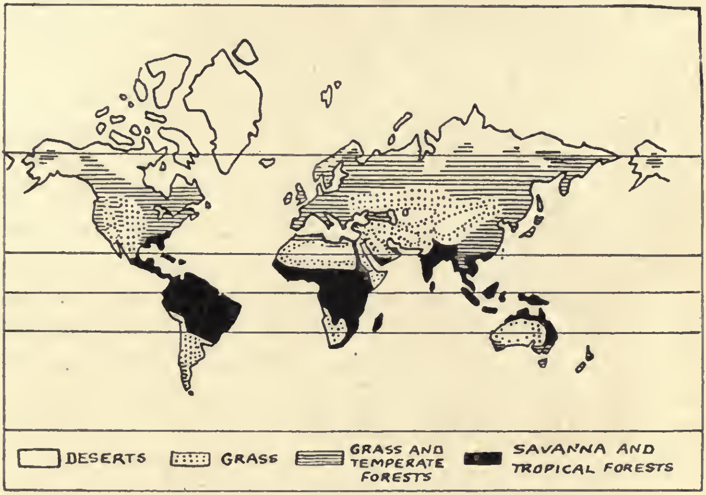


Fig. 61. Chief types of vegetation.

In places where the soil is undrained, the frozen subsoil, by preventing the water from soaking into the ground, converts the district into impassable swamps.

The few trees of the tundra are chiefly dwarf willows, birches, etc. They cling to the soil, not only to obtain heat, but also to avoid being injured by violent winds.

3. **Alpine or Mountain Flora.** The conditions are somewhat similar to those giving rise to tundra. On high mountains the winters are long and cold, and the plants

have to make the most of the short summer. The alpine flora is therefore very gay for a short time, and the trees cling close to the soil, as in the tundra.

It is not to be thought that the alpine and mountain plants are isolated patches of the Arctic flora. Both no doubt descend from lowland plants found on the great plains, when the temperature was much lower than at present; but, except for such distant connection, there is probably not a very close relationship between them.

4. **Temperate Forests.** For the growth of trees a relatively large rainfall is necessary, though it must be remembered that trees require much more water in a warm than in a cold region, for in the latter they do not transpire so actively as in the former. It is for this reason that forests are found in northern Saskatchewan while the southern part is covered with prairie, though there is little or no difference between the amounts of rainfall in the two regions. Temperate forests are divided into three zones.

(*a*) **Cold Temperate Forests** consist chiefly of coniferous trees, which in the north are smaller and become more and more stunted as the region merges into the tundra. The pines and firs withstand the winter by possessing thick leaves. Larches, however, shed their leaves.

(*b*) **Mid Temperate Forests** consist chiefly of deciduous trees which shed their broad thin leaves at the beginning of winter. Such trees are the oak, ash, beech, elm, etc. The British Isles, except part of Scotland, are in this zone.

(*c*) **Warm Temperate Forests** consist chiefly of evergreen trees, which possess thick leaves to withstand the dry summer, when too rapid transpiration is the danger to be avoided.

The temperate forest zone is more or less coincident with the zone of the moist antitrades. The vegetation along the Mediterranean fringes of the antitrade zones is, however, subject to a warm, dry summer. The drought is endured not only by a reduction of leaf surface and a thickening of the leaf cuticle, but in many cases leaves are protected by a felt-like covering of hair. Evergrey is more applicable than evergreen to such a vegetation.

5. **Grass Lands.** The forests become more open where rainfall is lighter, and in many places we find the trees restricted to the hill-tops, where elevation increases rainfall and reduces temperature, or to the banks of streams. The soil in other situations receives too little rain to allow of the growth of trees. Such grass lands are found on the equatorial sides of the temperate forest zone approximately in the horse latitudes. We have seen that in these latitudes the rain falls in winter and there is a hot, dry summer. These conditions are especially suited to the growth of wheat, and other cultivated grasses which need moisture during their vegetative period, but require a relatively hot, dry period for ripening their grain. Such regions are covered with flowers just after the rainy season. These herbaceous flowering plants go through their life-histories in a very short time, their seeds germinating at the beginning of the rainy season, while their fruit and seed are dispersed by the time the dry season is upon them. Others possess bulbs or rhizomes, and die down to these underground parts. During the dry season such plants are represented only by seeds, or underground parts which remain dormant in the soil until rain again comes.

Grass lands are often parched desert-like plains during the latter part of the dry season, and in higher latitudes far from the sea the dry season is followed by a long cold winter, when the region is swept by blizzards. This cold season is not without its advantages, for the frost and high winds powder the soil and renew the air within the soil spaces.

The grass lands are found on both sides of each of the trade wind zones, where the moving fringes of the equatorial rainy zone and the moist antitrade wind zones give them a rainy season.

(*a*) **Temperate Grass Lands** are between the temperate forests and the belt of trade wind deserts. They receive winter rains.

1. **The Steppes** of S.E. Europe and Asia extend from the Carpathians to the Altai Mountains. The Puzstas is a steppe region in the valley of the middle Danube, which possesses an exceptionally light rainfall on account of the encircling mountains. The southern part of this region consists largely of salt deserts. The river valleys are relatively fertile, however.

2. **Prairies and Grassy Plains** of North America are found between the Appalachians and the foot of the Rockies.

These grassy plains become drier towards the south-east, and merge into the great deserts of the N.E. trade wind zone.

3. **Karroo** is on the plateau south of the Nieuwveld Mountains in South Africa. Further north is the grassy **veld.**

4. **Pampas** are grassy plains around the Plate River in South America. They extend west to the Andes, and cover the greater part of the Argentine.

5. **Downland** is grass land in the southern part of Australia.

These grassy regions become drier towards the north, except the Pampas, and merge into the great deserts of the S.E. trade wind zone.

(*b*) **Grass Lands of the Torrid Zone** are between the belts of trade wind deserts and the equatorial rainy zone. They receive summer rains.

1. **Llanos** are found in the basin of the Orinoco.

2. **Grass Lands** of the **Sudan** and of the Monsoon Region of Asia.

3. **Campos** of Brazil.

4. **Park Lands** of South Africa between the Zambesi and the Kalahari Desert.

In regions where the inhabitants have tilled the soil for centuries, much of the land has been converted into grass lands by clearing natural forest land. In such regions forests are often left on the hills and mountains, where the soil is relatively thin. Practically all the lowlands of Europe are naturally forest regions, but, except in the eastern areas, much of it has been cleared and cultivated. In these regions the soil is exceedingly fertile, because of the vegetable mould which has been accumulated as generations of plants have died and decayed. A very large proportion of India has been cleared, but probably no country has been so thoroughly cleared as China. In both these countries the cutting of timber is regulated by government.

6. **Hot Deserts.** The great deserts occupy a belt in each trade wind zone between the two zones of grass land. The grass lands merge into deserts imperceptibly as the region becomes drier. The deserts lie along the tropics of both hemispheres. The daily range of temperature is very great, and consequently the rocks become broken into fragments, which are ground down into fine, rounded grains of sand by the action of the wind. The sand grains blown against hard rock wear it away as a sand-blast does, so that, except where crossed by rivers or where underground water reaches the surface, hot deserts are barren wastes of sand and are totally uninhabitable.

7. **Savanna.** On the fringe of the desert and in oases a few plants are found. These have to resist desiccation. Some have very thick leaves, or the leaves possess a covering of hair-like cells, which serve to restrict transpiration.

Many of the plants possess spines, so that animals shall not eat them. The cactus is probably the best known of these plants. The characteristic tree is the date palm, which possesses very long roots, penetrating deep into the sandy soil, and so obtains sufficient moisture. These palms are the principal trees in oases and are of the first importance in the lives of desert dwellers.

Nearer the equator, where moisture becomes more plentiful, vegetation becomes more abundant. Trees become more numerous. These grassy lands with open forests are often termed Savannas.

8. **Dense Tropical Forests.** Dense tropical forests are found where there is abundance of moisture and a high temperature throughout the year. This is the most luxuriant of all types of vegetation. Palms of every kind abound, while the trees are roped together with climbing plants, and innumerable orchids and other plants grow in the angles between the branches of the larger trees.

On account of the air being continually moist, the plants are in no danger of being dried up. In fact, the difficulty for them is to get rid of vapour at all. On this account we find in no other region such large and delicately formed leaves. So dense is the forest that the undergrowth is in perpetual twilight, and the air is so charged with moisture that water drips from the leaves of the trees.

In many places the floor of the forest is practically a swamp, so great is the amount of moisture present. In such places the amount of decaying vegetation is enormous, and forms breeding swamps, in which insects (such as the mosquito) pass through the earlier stages of their life-histories. Many of these creatures attack human beings and carry disease. Hence such districts are "malarial" and are unhealthy except for natives, who have become immune during the course of generations which have survived there.

Such forests are found in the basins of the Amazon, Congo, and Zambesi, as well as along the coasts of West Africa, East African coasts, Madagascar, Malay Peninsula, and the islands off the south-east of Asia.

CHAPTER X

VEGETABLE PRODUCTIONS

Wheat. Wheat is a cultivated grass which requires a fairly stiff soil, because the weight of the ripe ear renders the plant top-heavy. For the same reason, rains are harmful when the ear begins to enlarge. During spring and early summer there should be an ample rainfall for the vegetative growth of the plant. The moist season must be followed by a dry, warm season with a considerable amount of sunshine. The summer temperature ought not to be lower than 66° F. on an average.

Consequently wheat-growing regions are found where a wet season is followed by a dry, warm season. Evidently the regions naturally suited for wheat-growing are the grass lands of Mediterranean latitudes, where winter rains are followed by a dry, warm summer. Wheat is also grown in a naturally dry region where the soil is irrigated by rivers or canals.

The following are the chief wheat-growing regions :—

1. **European.** The northern limit is 62° N. lat., but very little is grown north of 55° N. Most of the wheat is grown between 40° and 50° N., but in Britain large quantities are grown as far north as 55° N. in the rain shadow along the east of the island. Most of the European countries do not produce enough wheat for home consumption, and consequently they import it. The chief areas

are the black lands of Russia, the plain of Roumania, the Puzstas of Hungary, the valley of the Po, and the plain of northern France and south-eastern Britain.

2. **American.** The grass lands west of the Great Lakes are being brought under cultivation to a continually increasing extent; wheat lands, which at first were restricted to the more easterly parts, are extending west along the river valleys and railways.

In the Argentine Republic wheat lands are increasing in importance.

3. **Asiatic.** The chief wheat lands are in the North-West Provinces and the Punjaub in India, where innumerable canals irrigate the soil. Wheat is also grown on the higher parts of the Deccan. The steppes of south-western Siberia are very similar to the prairies of North America, and are perhaps destined to rival them in importance as wheat lands.

4. **African.** The narrow valley of the Nile and the Nile Delta owe their fertility to the overflow of the Nile, which not only irrigates the soil, but also fertilizes it with mud brought from the equatorial forest region.

5. **Australian.** The south-east of the continent is the principal wheat-growing region.

Barley. Barley is a cultivated grass very similar to wheat, but it does not require such a high summer temperature, and consequently can be grown farther north and on higher land.

Oats. Oats are similar to wheat and barley, but will not tolerate too hot a summer. On the other hand, oats can endure considerable moisture, and are grown in moist regions such as mountain valleys in Scotland.

Rye. This cultivated grass does not require either the rich soil or the warm, dry ripening season needed by wheat. In Europe it is the chief crop on the lowland plains of the mainland between 50° and 60° N., and the people of North

Germany, Poland, and Russia use it to make the black bread which is their staple food.

Maize or Indian Corn. This cultivated grass is a native of the warmer parts of North America. It requires a considerable amount of moisture, and a long summer with a fairly high temperature. Consequently it does not grow much beyond the 40° N. parallel in America, and in Europe the 45° parallel is the centre of the maize-growing zone. It forms an important food of many tribes in tropical Africa.

Rice. Rice is also a cultivated grass. It forms the staple food of over one-fourth of the human race. Rice needs a far higher temperature than either wheat or maize, and it also requires abundant moisture; in fact, during its early stages it often grows under water in flooded fields. Consequently we find rice is cultivated in the hotter temperate and tropical regions, especially on deltas and flat alluvial soil which is rendered swampy either by natural or artificial irrigation. The principal rice-growing regions are:—

1. In India, the lower valley of the Ganges and the deltas on the east of the Deccan.
2. In China, the eastern plains.
3. In South Japan.
4. Nile Delta.
5. In Europe, in the valley of the Po, and on many of the Mediterranean deltas.
6. In America, in the south-eastern Atlantic coastal plain, which is sheltered from the cold north winds by the Appalachian highlands.

Rice is consumed principally in the regions where it is raised, the amount exported being relatively insignificant: consequently rice is of little commercial importance.

Millet. Millet requires a high temperature, but far less moisture than does rice. Hence it is cultivated on the drier lands to the east of the Deccan and in North China. It is the staple food of the people of India, and as its production in Central India depends on the south-west monsoons bringing sufficient moisture, a drought causes terrible famines.

Vine. In Europe the vine is grown as far north as the 50° N. parallel. It requires a summer temperature of at least 63° F., and must be free from frosts during summer. Moreover there must be a considerable amount of autumn sunshine to ripen the grapes thoroughly, otherwise the ripe fruit would contain too small a quantity of sugar to render wine-making profitable. The chief vine-growing regions are :—

1. **France.** Bordeaux (clarets), champagne, burgundy, cognac (brandy).

2. **Spain.** Andalusia (sherry), malaga.

3. **Portugal.** (Port.)

4. **Italy.** Italian wines do not keep well, and therefore are mostly consumed at home.

5. **Germany.** On the warm slopes in the Rhine Province.

6. **Hungary.** (Tokay.)

In Greece a small variety of grape is grown. It is termed the "Currant" and takes its name from the town of Corinth.

7. **Cape Colony.**

8. **South Australia.**

9. **California.**

Wine-making in South Africa, Australia, and California is of recent growth, but it is able to compete successfully with European wines on account of the purity of the former, when compared with the cheaper adulterated brands of the latter.

Sugar-cane. The sugar-cane is not unlike the maize, but it requires a very high temperature and a moist soil.

Consequently it grows chiefly in the torrid zone. The chief regions are:—

1. **West Indies.**
2. **Louisiana.**
3. **Brazil.**
4. **East Indies.**
5. **Queensland.**

Sugar Beet. The sugar beet requires merely a temperate climate for its cultivation. Most of our sugar is beet sugar, which comes chiefly from Germany, though small quantities come from France, Holland and Austria.

Tea. The plant is a native of Assam, where it is best grown. It is cultivated in regions where the temperature is moderate, where the rainfall is regular and heavy, and where the slope prevents the water from collecting around the roots of the plants. Hence the hill stations of India and Ceylon are favourable places. The healthy situations of these hill stations account for the fact that many Europeans become tea-planters in India. It is also cultivated in China, Japan, and Ceylon. In Japan it is cultivated as far north as 39° N.

Coffee. The fruit is a berry containing two hard-coated seeds, the coffee beans of commerce. The tree grows on the mountain slopes of tropical regions between elevations of 1000 and 4000 feet above the sea. The soil must contain a large proportion of vegetable mould and must be well-watered.

Its original home was the highlands of East Africa. It is now cultivated in many tropical regions, of which the chief are Brazil, West Indies, Venezuela, Guiana, Peru, Bolivia, Guatemala, Java, Ceylon, Sumatra, South Arabia, and West Africa.

Cocoa. Cocoa is obtained from the seeds of the cacao tree. It requires a hot, moist climate, and is grown in Trinidad, Venezuela, Ecuador, Brazil, and West Indies.

Banana. This fruit is cultivated throughout the tropical regions of the Old and New Worlds and forms the staple food of enormous numbers of people, and as a food it is second to no other plant, while at the same time it requires practically no cultivation. It is a native of the Old World. It requires a high temperature and abundant moisture.

Date. The fruit of the date palm is the staple food of desert people. It grows in oases and on the borders of hot deserts.

Sago. Sago is obtained from the pith of a palm tree, which requires tropical heat and a moist soil. It is obtained chiefly from the East Indies.

Tapioca. The cassava plant is a native of tropical America. Tapioca is obtained from the roots. It is cultivated in West Indies, Brazil, East Indies, and Central Africa.

Arrowroot. Arrowroot is a starch derived from the rhizomes of a plant of the Cannaceae. The plants require heat and moisture, and are cultivated in the West Indies and tropical regions of South America.

Potato. The potato plant was probably a native of Chile, but was extensively cultivated before America was discovered. It is suited to cool climates, where the summer is too short to cultivate grain successfully.

Spices.

1. **Black Pepper** is the dried fruit of a climbing shrub. It is grown on the Malabar coast, Malay Peninsula, Siam, and East Indies, as well as in the West Indies.

2. **Cinnamon** is the bark of a small tree. It is a native of Ceylon, but is cultivated in the tropical regions of both the New and the Old Worlds.

3. **Nutmeg**: the seed of a small tree which is a native of the East Indies. Cultivated in many tropical regions of the Old and New Worlds.

4. **Cloves**: dried flower buds of a plant which is a native of the East Indies. It is cultivated in East Indies, East Africa, Guiana, and West Indies.

5. **Ginger** is the prepared rhizome of a plant which is a native of South-East Africa. It is cultivated in the East and West Indies.

Opium. Opium is the dried juice obtained from seed vessels of a species of poppy which is grown in India, China, and Egypt, but the Chinese are getting rid of the opium traffic, and the Indian Government is proportionately restricting the cultivation of the plant.

Olive Oil. This oil is obtained from the fruit of the olive tree, which grows in the warmer parts of the temperate zone, especially on the European shores of the Mediterranean.

Lemons and Oranges. These are the fruit of trees growing in the warmer parts of the temperate zone. The oranges are grown principally in the south of Spain.

Cotton. The long, fibrous cells cover the seeds of the cotton plant and assist in their dispersal when the capsules open.

The cotton plant requires a high temperature, a heavy rainfall, and salt both in the air and in the soil. Thus we find that cotton-growing regions are near the sea in rainy districts in the warm temperate and torrid zones. The following are the principal cotton-growing regions :—

1. **United States.** The south-eastern coastal plain is the most important cotton-growing region in the world. Three-quarters of our raw cotton comes from this region. The finest cotton—the "Sea Island Cotton"—grows on the islands fringing the coast.

2. **Egypt.** The lower valley of the Nile.

3. **Brazil.** The Rio Janeiro district.

4. **India.**

(*a*) The hot moist region around the delta of the Ganges (Bengal).

(*b*) Western shores (Bombay Presidency).

(*c*) Berar, in the valley of the Tapti, produces some of the finest cotton in the world. Though it is far inland, the south-west monsoons blow up the valley, carrying the moist sea air far up the valley. Moreover the soil, which consists of decomposed volcanic rock, is sticky, and so retains its moisture.

Flax. Flax needs a fairly rich soil, but not a high temperature if grown for the sake of the fibre. It is grown in Russia, Belgium, and North Ireland for fibre.

But if the seed is required for oil, a warmer climate is necessary. The plant is cultivated for linseed in India and the United States.

Hemp. The plant is very similar to flax in its requirements. It is cultivated in Russia, Germany, Austria, Italy, and the Philippine Islands, as well as Arabia, Syria, and North India.

Jute. Jute consists of the fibres from the inner bark of a nettle-like plant which requires a very rich soil. Moreover it soon exhausts the soil. It is largely grown in the lower valley of the Brahmaputra, where floods bring down large quantities of rotting vegetation and strew it over the land.

Caoutchouc and Rubber. Caoutchouc and rubber are obtained from a number of different plants which grow in dense tropical forests. These rubber plants are tapped, and the juice collected in vessels. Crude rubber made from this is exported to manufacturing countries. The basins of the Amazon, Congo, and the Malay Islands are the principal rubber regions.

Tobacco. The tobacco plant is a native of America where half the total amount produced in the world is raised. The plant needs considerable moisture and a temperature about as high as that required for maize. Consequently it is grown in the warmer parts of the temperate zone, where there is a moderate rainfall. The chief regions are the states of Kentucky and East and West Virginia, France and Germany, as well as the West Indies.

Timber. Trees may serve many uses :—

1. The wood is used for buildings and furniture.

2. The tree may contain useful oils, resins, or sap (**turpentine, resin, eucalyptus, india-rubber, gums**).

3. The bark may be useful (**cork, quinine**—extracted from the bark—**tannin** in oak bark, making it useful for the preparation of leather).

4. Some wood is ground and boiled to form a pulp, from which the cheaper kinds of paper are made. This is usually made from the soft pine, spruce, and fir woods of cold temperate or mountain forests.

5. Charcoal is obtained by baking wood.

6. Certain products may be useful as food—**cane sugar** from the sugar maple of North America, acorns and beech nuts, useful for fattening pigs.

The principal trees are the following :—

1. **Coniferae of Cold Regions.** These trees grow on the lowland plains in the colder parts of the temperate zones, while in warmer regions they are found on mountains. Hence these trees are found on the plains of North Russia and Germany, as well as in the valleys of Sweden and Norway, and on the mountains of Central Europe. In the New World Coniferae grow on the highlands of the New England States and Canada and on the Pacific highlands, especially in British Columbia. The trees are chiefly **pines, firs, larches**, or **spruce.** All these grow rapidly, so that the wood has a coarse texture and is used for the rougher kinds of work and for pulp-making. Resin and turpentine are valuable products from these trees.

2. **Deciduous Trees.** These trees grow on the lowlands south of the pine tree zone and on the sides of hills lower down than Coniferae. They endure the winter by shedding their leaves. All the useful deciduous trees are of slow growth and possess in consequence a very close grain. Most of these trees produce wood which takes a high polish. Of these trees the oak is the best known, and the most important not only for buildings and furniture, but also for ships. Ash, elm, beech, and birch also yield valuable timber. Willows are useful for basket-making.

3. **Coniferae of Warm Regions.** Some of these, like the kauri pine and the common cedar, yield valuable timber, while sandal wood, box, and cigar box cedar (*Cedrela odorata*) are fancy woods.

4. **Tropical Trees.** Nearly all these trees have a very close grain and are very heavy. Some of them, like greenheart and teak, contain an oil which prevents insects or ship worms from burrowing into the timber. Mahogany is the best known, and is obtained from Central America, but an inferior kind is grown in Spain. Greenheart, which comes from Central America, is useful for piles driven in swampy soil. Teak is obtained from further India. Ebony is a hard, black wood.

CHAPTER XI

DISTRIBUTION OF ANIMALS

Habitat. Each species has usually a particular habitat, where alone it can survive in the keen struggle for existence. Thus the frog is restricted to marshy places, the freshwater crayfish to rivers, beavers to rivers, many insects to regions where a particular food-plant grows, coral to the sea from low water mark to a particular depth, and monkeys to forests.

Range. Always keeping to its habitat, a species may extend over vast areas. Thus gulls are cosmopolitan. On the other hand, some species are greatly restricted in their range; for example, the kiwi is confined to New Zealand.

Again, the range may be broken up, so that the species occurs in a number of stations.

Origin of Species. All species vary slightly from generation to generation. Those exhibiting variations most suitable for the conditions under which they live will have the best chance of surviving. The survival of the fittest, generation after generation, will cause new varieties and species to evolve in different surroundings. Consequently each species possesses an original home or centre of development, from which it dispersed to settle in its particular habitat found over a certain range.

Dispersal. Even the most slowly breeding animals tend to multiply to an enormous extent and would soon over-run the earth, if their numbers were not kept down by lack of food, by disease, or by beasts of prey. The keen struggle for food causes animals to disperse over an increasingly wide range as they become more numerous.

Some animals disperse much more readily than others. Thus strong flying birds, like the curlew, are found all over the world—keeping of course to their particular habitats. Some insects are carried hundreds of miles across the sea by gales. Many mammals can swim rivers and straits. Eggs and small animals are carried in the mud on the feet of birds to enormous distances. Drift wood and floating ice are also agents for dispersal.

Man has been the means of dispersing many species of animals. Thus rabbits have become a pest in Australia since they were introduced.

Barriers. The range of a species is limited by various barriers which the animal finds impassable. These are of very varying importance in the case of different species. Of these barriers the following are important :—

1. **Temperature.** Certain animals can only survive in regions where there is a particular range of temperature. Thus coral does not extend much beyond the tropics, except in a few regions where the local conditions (ocean currents, etc.) raise the temperature of the water to a sufficiently high degree.

2. **Oceans, Seas, Straits** vary considerably in their efficacy as barriers to different species. Thus the widest ocean offers no barrier to strongly flying birds, while the narrowest strait is impassable to the freshwater crayfish. The great difference between the fauna of Australia and New Zealand is due to the fact that they have been separated by a deep ocean for an enormous length of time, so that the new species which have been evolved since the regions were separated have been unable to pass from one region to the other.

3. **Deserts**, if sufficiently wide, are impassable barriers. Thus the Sahara Desert has prevented migration of species between the Mediterranean shores of Africa and the equatorial region. In fact, there is a greater difference between the faunae of Northern and Central Africa than between the faunae of the British Isles and Japan. Gorillas, chimpanzees, most of the lemurs, African elephants, hippopotamuses, and many other animals found in the central region are absent from the northern; while bears, deers, and oxen are absent from the central region though present on the northern side of the Desert.

4. **High Mountain Ranges,** especially if topped with perpetual snow, are impassable to a large number of animals. This accounts for the fact that a large number of species found in India do not extend north of the

Himalayas. The Indian elephant, rhinoceros, tapir, peacocks, and the jungle fowl are among such species.

Zoo-geographical Regions (Fig. 62).

1. **Palaearctic Region.** This region extends from the Arctic Ocean as far south as the Himalayas, the Arabian Desert, and the Sahara Desert—the southern boundary being not far removed from the Tropic of Cancer. It includes Europe (with Iceland), Northern and Central Asia, and Northern Africa. It possesses representatives of all families of higher mammals: but wild sheep, goats, oxen, deer, and other ungulata are characteristic, and it is to be observed that practically all the domesticated animals used by the human race have descended from wild species of this region, most probably from Central Asia.

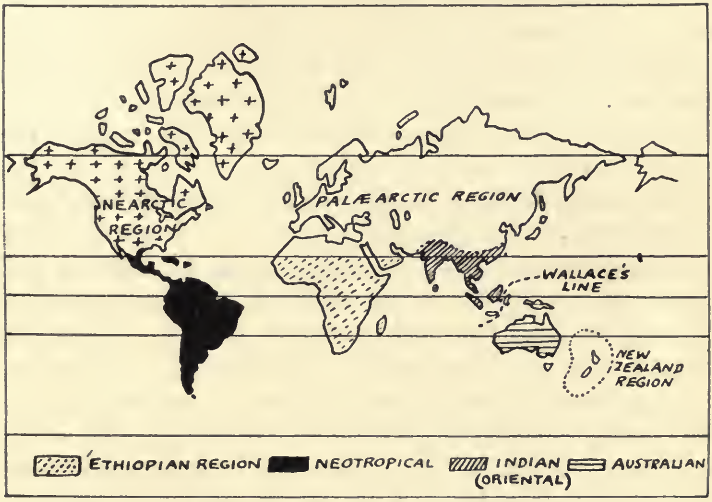


Fig. 62. Zoo-geographical regions.

2. **Nearctic Region.** This region includes America north of Mexico. The families represented are similar to those of the Palaearctic region, but the species differ in many of them.

3. **Ethiopian Region.** This region includes the whole of Africa and Arabia south of the Tropic of Cancer. Madagascar is often separated into a separate zoo-geographical region.

4. **Oriental Region.** This region includes India and South East Asia, as well as the islands as far east as "Wallace's Line," which passes between Bali and Lombok and between Borneo and Celebes.

5. **Australian Region.** This most interesting region includes Australia, Tasmania, and the Malay Islands east of "Wallace's Line." Almost all the higher mammals are absent, the mammalia being represented by Marsupials (kangaroos, opossum, etc.) and Monotremes (platypus and echidna). Moreover, most of these are not found outside the region. Similarly we find many birds peculiar to the region (emu, cassowary, lyre bird, etc.).

6. **New Zealand Region.** This region is sometimes included in the Australian region, but in it there are many species unrepresented in Australia, such as the kiwi and many other species of the same family, as well as all the species of Rhynchocephalia, a family of primitive lizard-like reptiles.

7. **Neotropical Region.** This region includes the tropical part of North America, as well as the whole of South America. The Neotropical region, which was probably quite separate from the Nearctic region within geologically recent times, possesses a large number of species peculiar to it. Among these are:—Prehensile-tailed monkeys, chinchillas, guinea pigs, jaguars, llamas, sloths, armadillos, ant-eaters, rheas, toucans, and hoatzins. Oxen, sheep, and swine are absent.

Domesticated Animals. The keen struggles between individuals of the human race, between tribes, and between nations, have had immense influence upon the evolution of man, but the struggles between man as a species and the other species of animals have also influenced his destiny. As primitive man spread over the world from his centre of development, he had not only the inanimate forces of nature to contend with, but also the ground had to be conquered from such giant mammalia as the mammoth, cave bear, sabre-toothed tiger, and the cave lion : and so the ingenuity of man was constrained in the direction of inventing defensive weapons. From being solely on the defence, advancing intelligence and the invention of better weapons enabled primitive man to assume the aggressive side and become a hunter.

1. **The Dog.** The dog is probably the most ancient of domesticated animals. Its ancestor was undoubtedly a wolf-like creature which hunted in packs : and man may have at first used the dog to assist him in hunting. Later on, as the social qualities of the creature were further developed, the dog gradually became man's friend as well as his helper. When the pastoral life was developed, the dog guarded the flocks and kept watch over the household.

The hunters in cold regions rely on the dog not only for the chase, but also as a draught animal ; but hunters in milder regions use larger domesticated animals for draught.

2. **The Ox.** The ancestors of the various breeds of oxen were probably animals which wandered over the grassy plains and forest clearings of the lowlands of Eurasia and America. The American animals were hunted, but never domesticated, while the Eurasian animals under the influence of man gave rise to the many different breeds which we possess to-day. These animals, first hunted for food, became domesticated, and were then used as milk givers and draught animals.

Oxen are pastured on the richer, moister lowland grass when required for dairy produce, but countless herds are now pastured on the drier grassy plains of all parts of the world for the production of meat, tallow, and hides.

3. **The Sheep.** Sheep descend from animals which inhabited the highlands of Central Eurasia. They thrive well on hill-pasture, and can survive on poor pasture on which cattle would starve. Though they are reared chiefly for wool, their flesh is eaten. Sheep are now reared on hill-pastures and on the drier plains in all parts of the world.

4. **The Goat.** These animals also descend from animals native in the highlands of Central Eurasia. Their ancestors inhabited much rougher and more elevated regions, and could tolerate far coarser food than the sheep. The common goat is reared mainly as a milk giver, but other species of goat, as the Angora and Kashmir, are reared for their wool.

5. **The Llama, Alpaca, and Vicuña.** These are mountain dwellers in South America. They are reared for their wool.

6. **The Reindeer.** The reindeer is used as a beast of burden and as a milk giver by the inhabitants of the sub-arctic regions.

7. **The Camel.** The camel is so thoroughly adapted to life in hot sandy desert regions that no other animal can compare with it as a beast of burden in desert regions. For ages it has been so employed in Africa and Asia, and it has recently been introduced into Australia. The two varieties are the two-humped Bactrian camel and the one-humped dromedary.

8. **The Horse.** The horse was domesticated on the steppes north of the highlands of Central Asia. It gradually took the place of the ox as a beast of burden and is often used as a milk giver. Its use as a charger in war probably made it the favourite beast of burden. Horses were introduced into America and herds of these horses roamed wild over the plains. Horses are used as beasts of burden and draught animals in lowland regions, and in highlands where roads are good.

9. **The Ass and the Mule.** The ass, descending from ancestors which lived in rough hilly regions where food was coarse, is hardy, surefooted, and can endure far coarser food than can the horse. This makes it a valuable beast of burden in rough districts where roads are absent, or very bad, and where pasture is poor.

The mule is surefooted like the ass, but is a larger and more powerful animal.

The ass was probably domesticated in Western Asia, and, together with the mule, is a common beast of burden around the Mediterranean and in the tropical regions of America.

10. **The Elephant.** This animal has been domesticated in the south-east of Asia, but it is much too unwieldy to be of any great importance compared with other beasts of burden.

11. **The Fowl.** The various breeds of domesticated fowl are said to have descended from the Indian jungle fowl. They are reared best on a dry limestone soil in a region where grain is produced in abundance. The plain of Hungary is such a region.

12. **The Duck and the Goose.** The duck is said to have descended from the wild mallard. Both the duck and the goose are less important than the fowl.

13. **The Silkworm.** The silkworm is the larva of a moth. The larva feeds on mulberry leaves and was first reared in China. From China the knowledge of silk-making spread into Japan; then to India, Persia, and Asia Minor. China, Japan, Bengal, and the countries around the Eastern Mediterranean are the chief silk-producing regions in the world.

In China cocoons produced by wild silkworms in the forests of the north are gathered and used.

Wild Animals.

1. **Fish.** There is no doubt whatever that the most important of wild animals to mankind are fish, and that fishermen are the most important hunters in the human race.

The three most important food fish are cod, herring, and salmon.

The chief fishing grounds are the shallow seas where seaweed can grow on the floor of the sea, because it is not too deep to allow sufficient sunlight to reach the weed. Seaweed provides food for fish and a place where they can lay their eggs. The eggs of the cod float while those of the herring sink. The cod prefers deeper water than the herring. The salmon ascends rivers to lay its eggs. Fish living in cold water are better for food than fish from tropical waters.

The chief fishing grounds are the shallow seas over the continental shelves in cold temperate regions—the most important being the North Sea and the Newfoundland Banks.

2. **Seals.** Seals are valuable for oil and fur. The animals are caught in the Bering Sea and off Newfoundland, where they are taken from the ice floes in spring.

3. **Whales.** These animals are caught principally for their oil, but also for whalebone. The chief whale fisheries are in the polar seas.

4. **Sponges.** Sponges are skeletons of marine animals which are attached to the bottom of the sea in warm regions. Sponges are obtained from the Mediterranean and from the shallow seas of the torrid zone.

5. **Coral.** Coral is the skeleton of a marine animal which lives in shallow water, and is not found much beyond the tropics.

6. **Pearl Oysters.** Pearl oysters are found in warm regions, chiefly in the Indian Ocean.

In many shallow, rather muddy estuaries oysters are reared for food. Owing to their position the oyster beds are liable to be contaminated with sewage, and are consequently often harmful.

7. **Elephant.** The elephant is hunted for its ivory tusks, though probably at present it is hunted for sport and is to be considered chiefly as big game. The ivory traffic was probably the chief cause of the slave trade carried on by Arabs in Central Africa.

8. **Fur-bearing Animals.** The bear, ermine, silver fox, marten, skunk, mink, arctic fox, are inhabitants of cold regions, where trapping is the only occupation carried on, unless the discovery of a precious metal attracts the miner. These animals are found in the cold temperate and arctic zones—most of the animals inhabiting the forest belt.

CHAPTER XII

THE SEA

The Floor of the Sea. The depth of the sea varies very greatly and the three conspicuous features are the continental shelves, the submarine ridges, and the intervening troughs (Figs. 63, 64).

1. **Continental Shelves.** These are the floors of the shallow seas surrounding the land masses, and their outer edges usually descend more or less steeply into deep water. These outer edges may be looked upon as the true borders of the continental masses. For example, the eastern border of Asia is the edge of the continental shelf just outside the chains of islands (**Philippines, Liu-Kiu, Japanese Islands, Kuriles, Aleutians**). The British Isles arise from such a

continental shelf, the western edge of which descends steeply into the Atlantic trough. Islands which rise from such a continental shelf are known as continental islands. The slope from the edge of the continental shelf is termed the continental slope.

Sediment brought down by rivers, as well as materials worn from coasts, are continually being strewn over the continental shelves. The sediment consists of sand, or mud, as well as more or less impure limestones formed from broken shelly skeletons of marine animals, mixed with sand or mud.

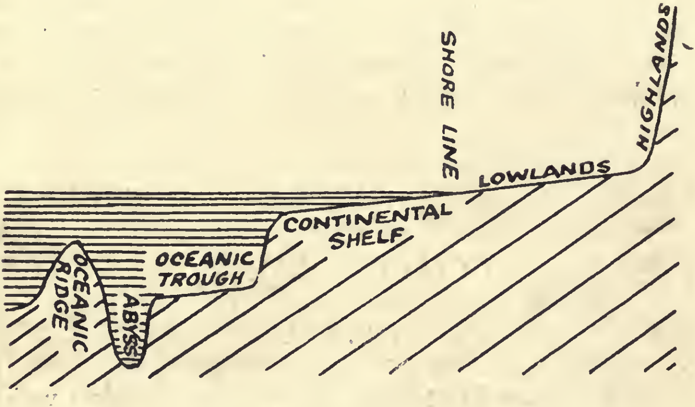


Fig. 63.

The principal fishing grounds of the world are the shallow seas over the continental shelves.

2. **Lowland Plains** may be looked upon as a part of the continental shelf which is raised above sea level. A very considerable portion of the lowland area has been raised above sea level during comparatively recent times, just as a considerable portion of the continental shelf has been depressed below sea level in comparatively recent times.

The gently sloping surface formed by the continental shelf and the lowland plain occupies about one-ninth of the total surface of the earth and is undoubtedly the most important part of the earth's surface, so far as living things are concerned.

3. **Oceanic Troughs.** From the edge of the continental shelf which may be taken as the 100 fathom line the ocean bed slopes rapidly down to troughs of varying depths, the average depth being about 11,000 feet. In these troughs are sometimes depths of 30,000 feet, but such abysmal depths are rare, and cover only a very small proportion of the ocean bed. They are always found near coasts bordering highland regions.

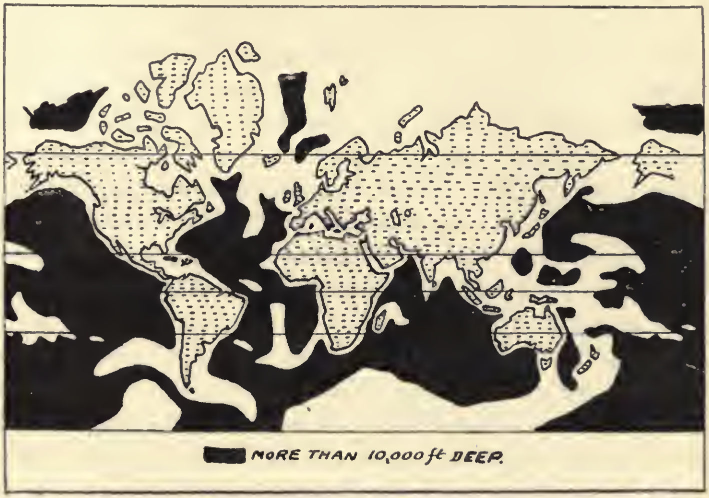


Fig. 64.

Except where such troughs approach within 300 miles of the coast line, they receive no sediment from the wearing away of the land—no sand, mud, or shallow water limestones. The deposits consist of the calcareous shells of dead animals which swarm in waters at the surface of the ocean far from land. The commonest of these deposits is known as Globigerina Ooze.

Where, however, the ocean is deepest, the shells are completely dissolved before they reach the ocean bed. In such places the deposit consists of red clay, containing meteoric and volcanic dust and shells which are not calcareous. Their existence is good evidence of the permanence of the great ocean basins.

4. **Oceanic Ridges.** These are ridges separating the deeper troughs of the oceans. From them often arise islands which are termed Oceanic Islands. Thus the Atlantic Ocean is divided into an eastern and a western basin by a ridge running north and south. This is known as the Dolphin Ridge in the North Atlantic and the Challenger Ridge in the South Atlantic. From this ridge arise the Azores in Lat. 40° N., St Paul near the equator, Ascension in Lat. 8° S. and Tristan da Cunha in Lat. 37° S. A little to the east of Challenger Ridge the island of St Helena rises up from the floor of the eastern depression at about Lat. 16° S.

Sea Water. Sea water consists of a solution of salts, the average amount being about 3·5 gms. to 100 gms. of water. The principal salt is **Sodium Chloride,** which amounts to about 2·7 gms. out of the 3·5 gms. of total salts. The other salts are **Magnesium Chloride** ·3 gm., **Magnesium Sulphate** ·2 gm., **Calcium Sulphate** ·1 gm., **Potassium Chloride** ·07 gm. Many other salts are present, but in small quantities only. Of these **Calcium Carbonate,** though present to the extent of ·005 gm. only, is of immense importance, as from it are formed all the calcium carbonate shells and skeletons of myriads of creatures inhabiting the sea. The skeletons of dead animals form the chalk and limestone deposits which make up a considerable portion of the sedimentary rocks of the earth's crust.

The composition of sea water varies slightly from place to place, and, as we have already seen, the density of the surface waters varies in different regions, the variation depending upon :—

1. Evaporation from surface.
2. Rainfall.
3. Supply of river water.

The dissolved matter is brought down to the sea by rivers which derive such matter from rocks through which, or over which, the rain water has passed. As evaporation merely removes fresh water from the ocean, while rivers continually bring dissolved matter to the ocean, it is probable that the sea water is becoming salter. Certain inland seas, which provide examples on a small scale, show this clearly. On a relatively small scale this increasing salinity is probably counteracted by the formation of shelly deposits of animal skeletons on the sea floor, and also by spray driven inland during high winds.

Temperature. The temperature of the surface waters varies with latitude. It depends also upon ocean currents. Thus in the almost closed Red Sea the surface waters often rise above 90° F. At the equator in the open ocean it is about 80° F. Around the British Isles it averages 55° F.

The mean daily range of temperature of the surface waters is about 1° F. That of the air immediately above is about 3° F. The annual range of the temperature of the sea around the British Isles is about 11° F. The effect of this low range on climate has already been explained.

The temperature also varies with the depth of the sea water, becoming colder and colder towards the floor of the ocean. At the greatest depths the temperature is not above 30° F., even at the equator.

Currents. The surface currents are caused by winds. For this reason we find that north of the equator the currents flow in such a direction as the waters would move if stirred clockwise. On the southern side of the equator they move as though stirred in a counter-clockwise manner (Fig. 65).

1. **The North Atlantic Drift** is the circular drift in the North Atlantic. The westerly drift from Africa to the West Indies is called the **North Equatorial Current**. It is the southern part of the North Atlantic Drift. A small part of the North Atlantic Drift enters the Caribbean Sea and, flowing round the Gulf of Mexico, emerges through the Florida Channel to join the main drift flowing along the eastern coast of America and across the North Atlantic to North-west Europe on the one hand and as a return current past Spain and Africa to the equator on the other. The "Gulf Stream," as the combined drift from the North Equatorial and the Mexican Gulf is called, helps the south-west winds to maintain their relatively high temperature, and in this indirect way, and only in this indirect way, does it affect the climate of North-west Europe.

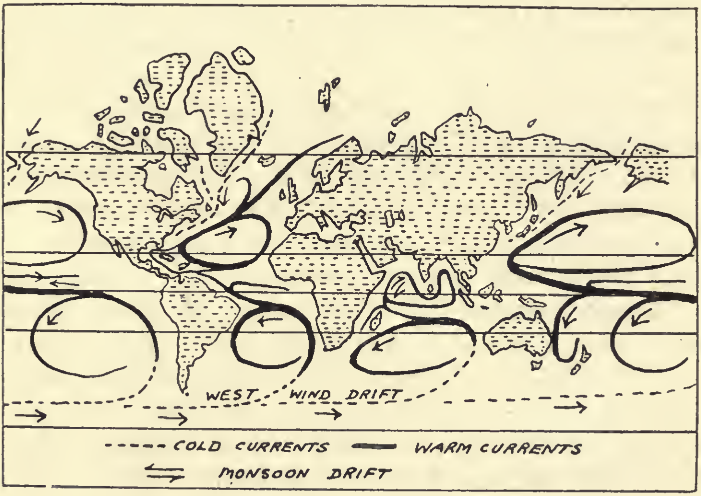


Fig. 65. Ocean currents.

2. **The South Atlantic Drift** is the circular drift in the South Atlantic. The northern part of this drift, the **South Equatorial Current**, is divided by the north-eastern shores of Brazil into two currents, one flowing along the northern shores of South America to join the north equatorial, while the other, known as the **Brazilian Current**, flows south along the coast as far as the Plate River, from which it flows east to the shores of Africa, returning as the **Benguela Current** along the south-west coast of Africa towards the equator.

3. **A Counter Current** flows east between the two drifts along the west coast of Africa.

4. **The Labrador Current** is a cold current flowing south between the Gulf Stream and the east coast of America. Where these currents meet, the mingling of the cold air above the one with the warm moist air above the other accounts for the dense fogs off Newfoundland. The meeting of the warm and cold waters causes the melting of the icebergs and the consequent formation of the famous banks from the débris embedded in them.

5. **Off Shore Winds**, such as blow over the Benguela Current, cause an upwelling of cold water from great depths.

6. **On Shore Winds**, such as blow towards West Europe, cause the warm surface waters to descend to greater depths.

The Pacific Ocean shows a very similar circulation of water.

The South Indian Ocean also shows a circulation similar to that in the South Atlantic and South Pacific. Madagascar divides the South Equatorial Current into two parts, one of which flows south through the Mozambique Channel.

In the North Indian Ocean the circulation is clockwise in winter but has a reverse direction in summer, consequent upon the changing of the monsoons.

In the Southern Ocean, swept by the brave west winds, there is a general easterly drift around the globe. This is supplied by the warm drifts from the north and cold drifts from the south.

The convection currents, set up by warm surface water moving from the equator towards the poles and the creeping of cold water along the ocean bed towards the equator, are of little importance in causing the circulation in comparison with the winds blowing over the surface.

Currents of Inland Seas. An inland sea, such as the Mediterranean, loses far more water by evaporation than it receives from rivers. Thus the water becomes denser than the water of the open ocean. Moreover, water enters from the ocean. This less dense water enters as a top current, while the denser water flows out of the inland sea as a bottom current.

In the case of an inland sea in a cold region, the loss by evaporation is often less than the supply of fresh water. Consequently the waters are less saline than those of the open ocean. Thus we find a surface current flowing out of the inland sea while a denser bottom current enters. The Black Sea and Baltic Sea are examples.

Coral. The reef-building corals flourish best in sea water which is not mixed with large quantities of fresh water from rivers. For this reason barrier reefs often exhibit gaps opposite river mouths. The Great Barrier reef of Australia shows such gaps. For the reef-building corals the temperature of the water must not fall below 70° F. and the annual range must not exceed 12° F. On this account coral reefs are not found much beyond the tropics, except in such cases as the Bermudas, which are in the track of the warm ocean current flowing north from the torrid zone.

The commonest formations are :—

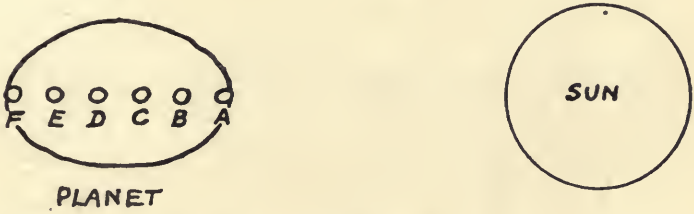
1. **Fringing Reefs**, which are formed along the shore just below low tide mark ;

2. **Barrier Reefs,** which are much further from the shore; and

3. **Atolls,** which consist of reefs surrounding shallow lagoons. These atolls, covered with coco-nut palms, are common in the warmer waters of the Pacific.

Tides.

1. **Cause.** A non-rotating fluid globe is held in a spherical form by the action of gravity between its particles, even if the temperature is so high that it is an attenuated gas in which cohesion is relatively insignificant. If such a fluid globe is put out of shape it will vibrate with a definite period, depending on its constitution, but will ultimately return to a spherical form if the disturbing force is removed.



DEFORMATION OF THE SUN IS NOT SHOWN

Fig. 66.

If another body (sun, moon, or planet) is situated at some distance from the first body, the mutual attraction between the two bodies will modify the shapes of both. Thus the two globes will be elongated along the line passing through their centres.

Some idea of the reason for this deformation may be gathered by considering the action of gravitation along the straight line drawn through the centres of the two globes. If both bodies continually present the same faces to one another, the particle *A* (Fig. 66), being nearest to the sun, will be more strongly attracted than particle *B*, *B* more than *C*, *C* more than *D*, and so on, while *F* will be attracted least strongly of all. This differential action of gravitation between the two globes will tend to stretch the globe along the diameter *AF*, while there will be a corresponding shortening along the diameters at right angles to *AF*.

It must be remembered that the centrifugal force of the revolving bodies about their common centre of gravity will keep them at a constant distance from each other.

The action of gravity between the particles of the fluid globe will tend to keep it in a spherical form, and hence the deformation is a compromise between the result of the action of gravity between the particles of the globe and the effect of the differential action of gravitation between the particles and the other globe.

Now consider the deformation in the case of a solid globe covered with water of a uniform depth. As the solid globe is much more rigid than a steel globe, we can neglect its deformation compared with that of the layer of water. The latter will be affected in the manner explained above, and hence the results which follow are :—

(*a*) The water will be deepest at two places—one at each end of the diameter which is in the line joining the centres of the two bodies.

(*b*) The water will be lowest along the great circle at right angles to this diameter, and passing through the poles.

(*c*) The greatest difference between these depths along any parallel will be found along the equator.

(*d*) Along the parallels of higher latitudes the difference will decrease with distance from the equator, and will disappear at the poles.

(*e*) Along any parallel there will be two positions of high water and two of low water, the high water occurring on the meridian opposite the sun and on the opposite meridian, the low water on the two meridians 90° from the high water positions.

2. **Spring Tides** (Fig. 67). Now consider the effect on the tides when sun, moon, and earth are in the same straight line at fixed distances from one another, but with the earth continually presenting the same face to moon and sun.

This would be the relative positions of the bodies at new moon. Clearly the deformation of the liquid layer would be much greater than before—high water would be higher, low water would be lower. A similar state of affairs would be found at full moon, that is, at the end of the moon's second quarter.

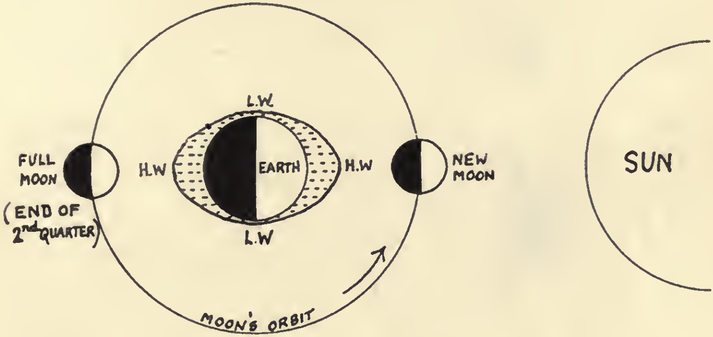


Fig. 67. Spring tides.

Such tides are called Spring Tides. They occur at approximately fortnightly intervals, at new moon and full moon. The tides rise higher and sink lower at these times than at any other time in the lunar month.

3. **Neap Tides** (Fig. 68). At the end of the first quarter and at the end of the third quarter the tide-forming influence of the moon acts at right angles to that of the sun. The one tends to neutralise the effect of the other. If their tide-forming influences were equally great, the water would be uniformly deep along any parallel. But the tide-forming influence of the moon is nine-fourths of

that of the sun. Consequently there would be high water on the meridian facing the moon and on the opposite meridian, while low water would be on the meridian facing the sun and on the opposite meridian.

Moreover, high water would be lower than during spring tides and low water would be higher than during spring tides, that is, the difference between high water and low water would be less than during the spring tides. Such a state of affairs occurs at half moon, that is, at the end of the first quarter and at the end of the third quarter. These low tides are called Neap Tides.

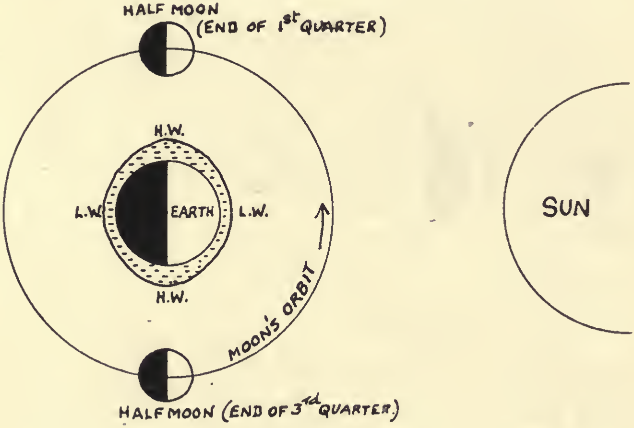


Fig. 68. Neap tides.

At other times in the lunar month high water and low water will have intermediate values.

4. **Tidal Waves.** So far we have considered the bodies as fixed in position and the earth as non-rotating, so that there is no wave motion to complicate matters.

We must now imagine the earth as rotating from west to east. It follows that high water and low water will tend to move round the solid globe from east to west. We can imagine a tidal wave with two crests alternating with two troughs sweeping round the globe. The matter then becomes still further complicated.

(*a*) The wave, once formed, has a natural velocity which has nothing whatever to do with the earth's rotation.

The moon revolves round the earth from west to east in about 27⅓ days. Therefore the time between two consecutive transits of the moon across the meridian at any place is about one-thirtieth of 24 hours longer than a mean solar day: that is, about 24 hours 50 minutes. It is this which causes the tides to be about 50 minutes later each day, the interval between the times of two consecutive instants of high water at any place being about 12 hours 25 minutes.

Evidently, if the position of high water is to remain facing the moon, the natural velocity of the wave must enable it to sweep round the globe in about 24 hours 50 minutes. But to attain this velocity the liquid layer would need to be far deeper than the deepest part of any of our oceans. As a matter of fact the natural velocity varies according to the depth of the ocean, and in our oceans the depth is everywhere far less than is required for the necessary velocity to be attained. Therefore the position of high water is to the east of what we might at first expect. Under certain conditions, high water might occur where at first low water might be looked for. This is what is known as the inversion of the tide.

(*b*) Another factor to consider is friction. The friction between the solid globe and the liquid layer would tend to neutralise the effect of inversion. Therefore the position of high water would not be so far to the east as we might suppose if inversion alone were considered.

So far, then, we can imagine the tidal crests and troughs sweeping around the earth from east to west, high water occurring somewhere between 0° and 90° E. of the meridian facing the moon.

(*c*) The oceans are not uniformly deep, and it follows that the natural velocity of the tidal wave will vary along any parallel from place to place, being greatest where the water is deepest and slowest where the water is shallowest.

On a small scale this can be seen on the sea shore. The crests of the waves get nearer and nearer together as they sweep over the shallower water which covers the beach.

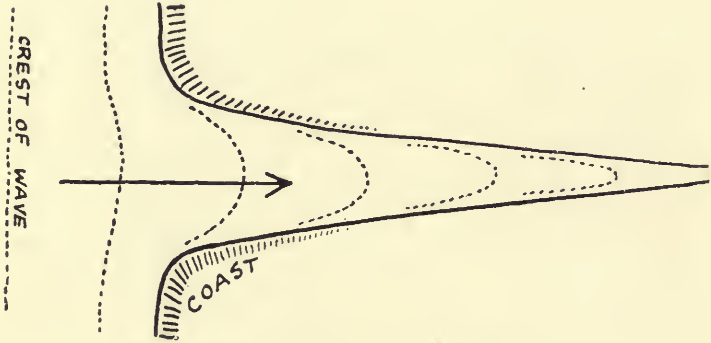


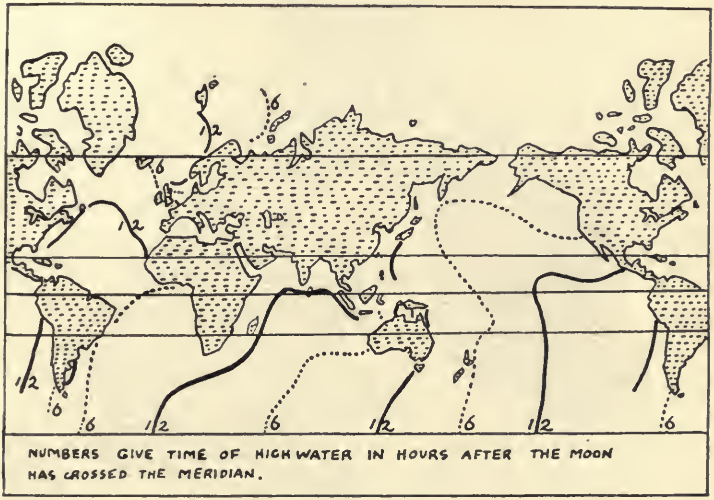
Fig. 69. Waves entering an estuary.

Again, we may observe the waves entering a small river mouth. The crest of the wave becomes more and more convex as it rushes up the estuary, that part of the wave near the shore being retarded in the shallower water (Fig. 69).

Co-tidal lines are lines joining points where the tide is at the same state at the same moment.

Now examine Fig. 70, and note the forms of the co-tidal lines in the Pacific. The 12 hour crest is convex towards the north-west, its most advanced point being just north of the equator at Long. 150° W. The crest sweeps across the Pacific, but not at a uniform rate. A comparison of Figs. 64 and 70 shows that over deep water the crest reaches Kamchatka in six hours, while across shallower water it has only been able to reach San Francisco and New Zealand. An examination of the six hour and twelve hour crests in the Atlantic will provide another illustration.

(*d*) Land masses divide the wave into parts and direct the movement of the wave away from its normal east to west course.


6
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NUMBERS GIVE TIME OF HIGH WATER IN HOURS AFTER THE MOON HAS CROSSED THE MERIDIAN.

Fig. 70. Co-tidal lines.

Thus the tidal wave sweeps over the Atlantic from south to north, and along the English Channel from west to east, in the latter case taking a course which is directly opposite to the course it would pursue if there were no land.

Moreover a wave undergoes reflection on reaching a shore. On a very small scale this reflection is shown when the smaller waves (" wind " waves) strike a cliff standing out of deep water. Exceptionally high waves are formed by the meeting of a reflected wave with a later on-shore wave. The very high tides of the north Cornish coast may

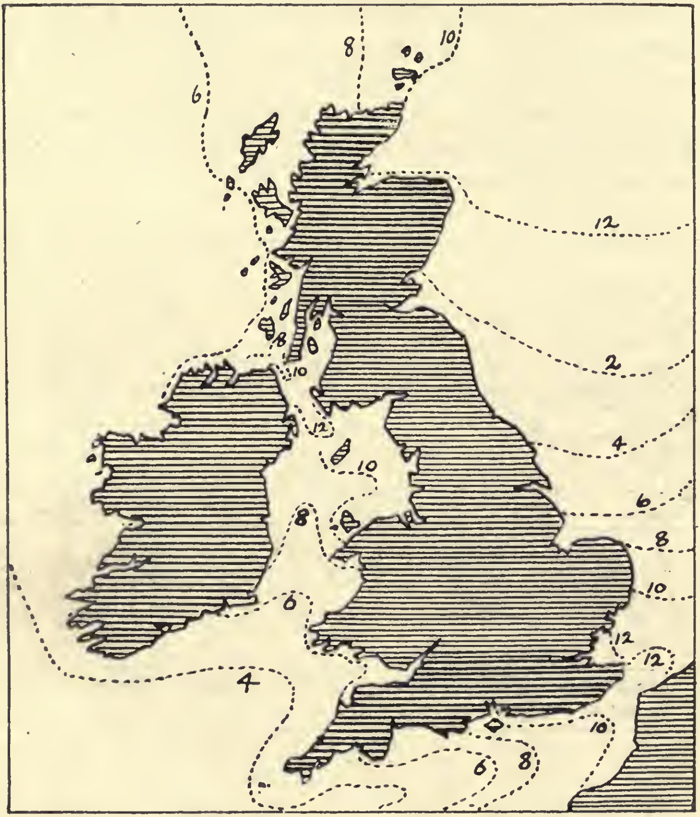

Fig. 71. Co-tidal lines.

be partly accounted for by considering the reflection of tidal waves from the Welsh coast. Again, the meeting of the tidal wave up the English Channel with the wave which has swept over the North Sea from north to south helps to explain the high tides in the Thames, giving London one of the conditions which make it a great port (Fig. 71).

In V-shaped estuaries and inlets the tides increase in height and often form "bores," which are sometimes dangerous to shipping, but often allow large ports to exist further inland than would be possible otherwise. The Bay of Fundy, the Bristol Channel, the Hugli, and the Yangtzekiang provide examples. Bristol stands six miles above the mouth of such a small river as the Avon. The double falls in the mouth of the St John river in New Brunswick are the result of such high tides.

Southampton water possesses four tides each day. The earlier tide sweeps up the Solent and enters Southampton water. Two hours later the other part of the wave passing round the Isle of Wight comes up the Spithead and enters Southampton water. On this account the water at Southampton is deeper at all states of the tide than might be expected.

In certain places the tide causes a strong current to flow. This usually occurs in narrow straits, where there is a considerable difference in the times of high water at opposite ends of the strait. In the Pentland Firth the flow and ebb currents run at the rate of over six miles an hour. Such a current is called a tidal race.

In a bottle-shaped estuary the tides prevent the deposit of sediment in the neck, while the tidal range in the estuary is less than the tidal range outside. The estuaries of the Mersey and its neighbour, the Dee, may be contrasted in this respect.

CHAPTER XIII

DISINTEGRATION OF THE CRUST OF THE EARTH

Crust of the Earth. The crust of the earth is that part of the solid globe which is accessible for observation. It includes those parts, the constitution of which can be inferred with reasonable confidence, even though not accessible to observation directly.

Rocks. A rock is a mass of natural substance which goes to make up the earth's crust. Slate, sandstone, limestone, chalk, clay, etc., are rocks.

Minerals. Minerals are constituents of rocks, possessing a definite chemical constitution. Quartz, felspar, calcite and various ores are minerals.

Agents of Disintegration.

1. **Heat and Cold.** During the day rocks become warm, but during the night they become cold : they expand during the day and contract during the night. This alternating expansion and contraction causes the rocks to crack, especially in their superficial layers. In some of the desert regions, where the daily range is often 100° F. or more, pieces of rock break off with a sound like the report of a gun.

2. **Frost.** Once fissures or cracks are formed, rain water enters them. This water, when frozen, expands and opens the fissures, just as freezing water bursts water pipes. If a rock is porous, it absorbs a considerable amount of water, which upon freezing breaks up the rock.

3. **Wind.** When particles are broken off the solid rock, the wind blows them to and fro, and the particles not only wear away one another but also wear away the surface over which they are blown. In dry regions where there is

no vegetation to prevent the small particles being blown over the surface, the soil consists of sand, while the exposed bare surface of the rock is polished. In some districts the wind, driving the particles against the outstanding masses of rock, causes them to be undercut, and, as the lower part will be worn most often by the sand blast, the masses of rock often stand on small supports, and may form "logan rocks" or "rocking stones."

4. **Rain.** Of the water falling as rain—

(*a*) A part is immediately returned to the atmosphere by evaporation.

(*b*) A part collects in little rills, which flow over the surface. This washes the particles of rock from a higher to a lower level, and in the process the particles grind one another away, and also wear away the surface over which they are moved, the rills cutting their channels deeper and deeper.

(*c*) A part of the rain soaks into the ground, entering the spaces of the soil and penetrating the fissures of the solid rock. The rocks themselves, being more or less porous, become saturated with water.

In falling through the atmosphere, the rain dissolves the gases which constitute it. Of these, carbon dioxide and oxygen are the chief. The oxygen dissolved in the water oxidises certain constituents of the rocks. The carbon dioxide enables such "carbonated" water to dissolve carbonates. Other acids derived from vegetable soil also enable water containing them to dissolve and decompose certain rocks.

It is such solution which causes spring water to be hard, especially spring water which has percolated through limestones; and solution accounts for the formation of caverns in limestone rocks. The Peak Caverns, the Cheddar Caverns, and the Mammoth Cave in Kentucky are examples.

Rivers in limestone regions often form deep gorges, such as the Avon Gorge at Clifton; or gaps in softer chalk ridges; the Goring gap on the Thames is a good example.

In Ireland the rivers flowing over the limestone plain are widened into large lakes. In this case solution is rendered more rapid by the acid water draining from bogs. Often such rivers flow underground for a considerable distance. Mask and Corrib are two lakes connected by such an underground stream. In the Balkan Peninsula many rivers disappear in sinks or katavothras, and some issue from the bed of the sea miles from the coast, the fresh water rising upwards through the denser sea water.

By the action of rain water granites are decomposed and deposits of kaolin (China clay) are formed. Examples of such deposits are found in Devon and Cornwall.

Earth pillars are peculiar features in certain districts where the rains are heavy, and where a relatively soft soil contains numbers of stones. Where the stones do not protect the soil from rain the soil is washed away, and earth pillars, each capped by a protective stone, remain standing.

5. **Rivers.** Rivers are the result of the union of streams. The sources of their water supply are—

(*a*) Rain running from the surface in the drainage area,

(*b*) Spring water which has its origin in rain water percolating through rocks, and

(*c*) In some cases melting snow and glaciers also provide water.

Laws of flow—

(*a*) Inclination of the river channel. The steeper the gradient, the more rapid will be the flow.

(*b*) Volume of water in the channel. The greater the volume of water, the more rapid the flow. Hence the velocity of a stream is greatest during floods.

(*c*) Friction on the river bed. Friction on the bed of a river retards the velocity of the stream. The velocity is greatest at the mid point on the surface of the stream. The velocity decreases towards the sides and towards the bottom.

Transport of suspended material.

All earths and stones lose about one-third of their weight when suspended in water. Thus only two-thirds of the force needed to raise them in air is needed to lift them in water. Still less is needed to roll pebbles along the river bed.

Erosion. The erosive power is due to detritus carried along. The effective force is the running water. The tools are pebbles, sand, and mud.

The rapidity of erosion depends upon—

(*a*) Volume of water,

(*b*) Velocity of the stream,

(*c*) Character of the rocks over which the river flows, and

(*d*) The load of detritus carried by the stream.

The stones, etc., falling into the stream are gradually worn away and rounded to form pebbles. The pebbles and smaller particles are ground down into finer and finer particles, which in turn wear away the banks and bed of the stream, so that the valley will be lowered by this means. Where eddies are formed, the circular motion of the pebbles wears away a "pot-hole," and in many valleys where the rocks are hard, pot-holes are numerous. They are often found far above the level of the stream, showing that the river has lowered its channel since their formation.

The great velocity of a stream over the ledge of a cascade gradually wears away the ledge and causes the cascade to recede. The Niagara Gorge, formed in this way, is many miles in length.

Cañons are deep narrow valleys with precipitous sides.

They are found in regions where the strata are more or less horizontal and where the rainfall is very light, the supply of water entering the river mainly in its upper course. Consequently there are not a large number of little rills wearing away the banks of the stream and widening the valley, giving it the gently sloping sides to which we are accustomed in England.

The river cuts a deep valley, which is very narrow in comparison with its width. The Grand Cañon in Colorado is in many places more than a mile deep. On each side of this cañon are tributary cañons, receiving their water from distant snow-clad regions.

In the West Central States the tributaries of the Mississippi have formed cañons on a smaller scale, cutting up the horizontal strata into flat-topped mesas.

The fact to be remembered is that the gorges are steep and narrow in proportion as the rocks are hard and the rainfall light.

Glens. The greater part of Scandinavia and Scotland consists of very old hard rocks so that the destructive agents of the atmosphere have little effect on them compared with the action of the mountain torrents, which are so numerous in these regions of heavy rainfall. Hence the valleys are deep and narrow, though the plentiful rainfall, causing numerous rills down the valley sides, rounds and smooths away the angularities, preventing the formation of precipitous sides, such as are seen in cañons. Detritus is washed from the hill sides into the floor of the valley, and there forms a fertile soil. We find most glens possess more or less fertile valley floors, bounded by barren hill slopes and uplands, which are covered with rough grass and heather, leaving exposed here and there bare, smooth, hard rock surfaces.

In many cases, where two glens have been carved out on opposite slopes of a watershed, the water parting has been reduced first to a comparatively sharp edge between the two glens: later on the sharp edge is worn away until the valley is continuous from sea to sea, the divide being indicated by the point of highest elevation in the valley floor. Such a place forms a col, saddle, or pass. These cols are common in Scotland and allow of communication by road and rail between opposite slopes.

Probably the best known, and perhaps the most important, of such passes in economic and military history is the Adige and Trent valley connecting the plain of northern Italy with the upper Danube.

Valley lakes, ribbon-like and often fantastic in shape, are commonly met with in glens. They may have been formed in several ways—

(*a*) **By Earth Movements.** Many glens are carved out in very ancient rocks and the glens themselves are often of immense age. During their formation there must have occurred many changes in the height and slope of the land, and it is not to be wondered at that the valley floors have been rendered uneven and that glen lakes have been formed in the hollows. The valley lakes in Glenmore, which is a very ancient river valley, are excellent examples of lakes which may have arisen in this way.

One must not forget, however, that the tendency of river action is to fill the lake with detritus at its upper end while cutting its outlet lower at its lower end so that, acting alone, the river action would cause the lake to disappear.

(*b*) **Moraine Dams.** The masses of rock which glaciers carry on their surfaces, or along the floor over which they move, are ultimately transported to the lower end of the glacier, where the ice melts. There the material is deposited, and forms a dam across the valley. Ages after the glacier has disappeared, the moraines left at different levels along the valley remain, and serve to dam back the water and so give origin to valley lakes. In Scotland, Wales, and Switzerland, as well as in other regions, such lakes are not uncommon.

(*c*) **Ice Action.** Geologists are not agreed as to whether or not glaciers can carve out hollows in their valleys.

When subsidence occurs in a region which has been carved into glens, the sea will invade the glens and form long narrow deep inlets called Fiords. These are common on the west coast of Scotland, but are found on a far grander scale in Norway. Sogne Fiord penetrates inland to a distance of nearly a hundred miles. Similar inlets are found on the west coast of Ireland, while the Fal and Dart are examples in Cornwall and Devon.

Such coasts also exhibit a fringe of islands, called Skerries. These islands act as a natural breakwater, and render the water between them and the mainland calm. British Columbia, Scotland, Norway, and Southern Chile possess such a fringe of skerries.

Wide River Valleys. Wide river valleys occur in regions where the rock is soft. The surface slopes gently upwards from the river to the water-parting. The rivers flow over an almost level plain, and the divide between adjacent river basins is scarcely marked by even low hills. The Great Plain of Siberia illustrates this very well. Where subsidence has occurred, the lower part of the river valley is filled with sea water and a shallow estuary is formed. In regions where the rainfall is adequate and the temperature sufficiently high, wide shallow valleys are often very fertile and densely peopled, while important ports stand on the estuaries. The Thames is a very good example of such a valley. The great civilizations of China, India, Mesopotamia, and Egypt arose in plain-like valleys possessing favourable climates.

Importance of Rivers. It is difficult to over-estimate the importance of rivers to the growth of civilization.

Rivers irrigate the soil during floods, and strew over the valley a fertilizing mud brought from its upper course, and often render artificial manures unnecessary, even though crop after crop is taken from the soil. Such regions were very soon densely peopled, when man had arrived at the agricultural stage. The fertile area is often extended by artificial canals, which irrigate the soil further away from the naturally irrigated area.

As a means of communication rivers are of prime importance, and the facility with which they allow merchandise to be transported has a direct bearing on the growth of trade, and also on the dissemination of ideas and the growth of civilization. In this way rivers tend to prevent insularity. The value of rivers for communication is further increased by the construction of canals connecting them, while commerce is increased by the canalization of the lower course of the river.

In river valleys towns usually grow up at confluences, at fords, or where the river can be bridged, as well as where important roads or railways may reach the river. An over-sea commerce often passes through a large port on the river mouth. To the life of a town the river is important as a supply of fresh water, and it also acts the part of scavenger. In its waters the organic matter is soon decomposed into harmless simple chemical substances, and towns lower down the river do not suffer as one might expect. Towns built on the "peninsula" in the bend of a river are partly surrounded by a natural moat and, in early times at any rate, were difficult to attack.

Again, as a source of power, rivers drive water wheels, and in modern times are often the indirect means of generating electrical power.

As a source of fish useful for food, rivers are of very little importance, at least in recent times, except in cold regions where a people in the hunting stage of civilization may eke out a precarious existence by river fishing. In China, however, where a teeming population renders it necessary to make use of every resource, fresh water fish are not only used as food, but pisciculture is practised to a high degree of perfection.

When rivers are political boundaries, they are, almost always, purely artificial boundaries, or rather arbitrary frontiers. People living on opposite banks of the river rarely differ ethnologically, while their economic interests are usually identical, and in cases where they are politically hostile, they are enemies mainly from tradition. In any case the river is of less importance to them as a frontier than it is to their compatriots further removed from its banks.

As a general rule, we may take it that a river valley will be, more or less nearly, a geographical unit, or will form part of one.

6. **Glaciers.** Glaciers are streams of ice which receive their supply from snow which collects in hollows above the snow line. The collecting ground is termed the firn or névé.

(*a*) **Motion.** As in a river, so in a glacier the motion is most rapid in the centre and least rapid at the sides. The Mer de Glace in the Pennine Alps moves twenty-seven inches in twenty-four hours in summer, and about half as fast in winter. Moreover, it reaches further down the valley in winter than it does in summer.

(*b*) **Transport of Detritus.** Particles of all sizes fall on to the surface of the glacier from the sides of the valley, forming lateral lines of detritus. These are called lateral moraines (Fig. 72). Where two glaciers unite, two lateral moraines coalesce to form a median moraine. If there are several tributary glaciers, there will be several median moraines. The detritus, which is ultimately thrown down at the end of the glacier, is called a terminal moraine. It will form a dam across the valley.

Materials are also embedded in the ice. In fact, a lump of glacier ice melted in a tumbler of water causes the water to become turbid with suspended matter. In summer, streams of muddy water course over the surface of the glacier, and, falling into crevasses, form a turbid stream issuing from beneath the ice at its termination lower down the valley.

(*c*) **Erosion.** Materials embedded in the lower surface of a glacier scratch, groove, and wear away the rocks over which they pass, and long after the glaciers have disappeared such scratches, as well as rounded roches moutonnées, and perched blocks, indicate the former presence of glaciers.

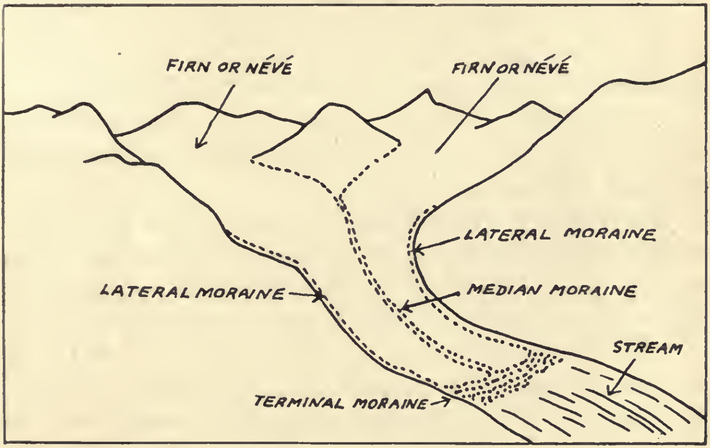

Fig. 72. Glacier.

(*d*) **Icebergs.** Where glaciers reach the sea, in cold regions, huge masses are broken off, and, being less dense than water, these icebergs float and are carried away by currents.

As they reach warmer regions the icebergs slowly melt, the débris embedded in them falling to the floor of the sea. In this way the icebergs brought by the cold current from Greenland are melted rapidly on meeting the warm Atlantic drift off Newfoundland, and the famous "banks" are generally looked upon as being débris fallen from the melting icebergs. Moreover, on reaching lower latitudes, where the warmer air contains considerable moisture, the icebergs chill the air, lowering its saturation temperature, so that dense fogs are formed. The cold air over the cold ocean current also brings about a similar result on mixing with the warm moist air.

The icebergs bringing the seals from the north also give rise to the seal fishing off Newfoundland. Unfortunately the icebergs reach as far south as the track of the ocean going vessels to and from North-eastern America, and are a source of danger to shipping.

7. **The Sea.** The waves of the sea are caused by wind. Waves are able to wear away the coast on which they beat, for the following reasons :—

(*a*) They beat the rocks with considerable force. During storms the force of the waves is often as much as three tons on every square foot. This of itself would be sufficient to break off projecting masses of rock.

(*b*) Water is forced into the crevices of rocks, and by opening them helps to break away masses.

(*c*) Air in still smaller crevices is compressed and helps to open them.

(*d*) The stones and boulders broken off are employed as battering rams, and not only become worn away and rounded, but also wear away the rocks against which they are hurled.

In this way the sea waves wear away the coast between tide marks, breaking the rocks down into boulders, pebbles, sand, and mud, which are strewn over the sea bed and the almost level beach which the sea has planed from the irregular land. If the rocks are hard, the atmosphere may have far less power of destruction than the sea, and the cliffs will be precipitous, or even overhanging; but if the rocks are soft, the destructive action of the atmosphere gives to the cliff face a slope seaward, the inclination depending on the softness of the rock. The dip of the strata has a very great influence in cliff formation. Hard rocks, dipping away from the sea, will be undercut and worn into caverns, but if the rocks dip towards the sea, the cliffs will slope more gently seaward.

CHAPTER XIV

DEPOSITION OF DETRITUS

THE load which moving water can carry varies according to the rate of movement. Thus as water moves more and more slowly, it will deposit a part of its suspended load as a sediment on the bed over which it moves.

Deposition in a River Valley. Near its source, if the river is a mountain torrent, the sediment on the bed will be principally pebbles and boulders. The sand and mud will be carried further down by the rapidly moving stream.

Further down, where the stream moves less rapidly, the bed is gravelly, the particles being smaller than the pebbles in the torrent.

Still further down, one finds coarse sand, then fine sand and mud, the sand and mud becoming finer and finer towards the mouth of the river.

This gradual change in the nature of the sediment is never found to occur just in the above simple way. Many causes determine the nature of the sediment. Among these the following may be noted:—

1. Lateral streams may wash pebbles or gravel into a main stream, where otherwise only sand and mud would lie on the bed.

2. The sectional area at different parts of the course of a stream may vary in an irregular manner. Thus a stream may be narrow and shallow in a particular spot (Fig. 73). In such a place the velocity of the stream will be greater than the velocity above and below. Consequently only large particles (say coarse sand and gravel) will lie on the bottom at this spot, while above and below the bed may be muddy. It is interesting to note how often villages sprang up at such spots. The reason is clearly the fact that the shallow stream and the firm gravelly bottom at this spot make it an excellent ford. Hence also the large number of place names ending in **-ford.**

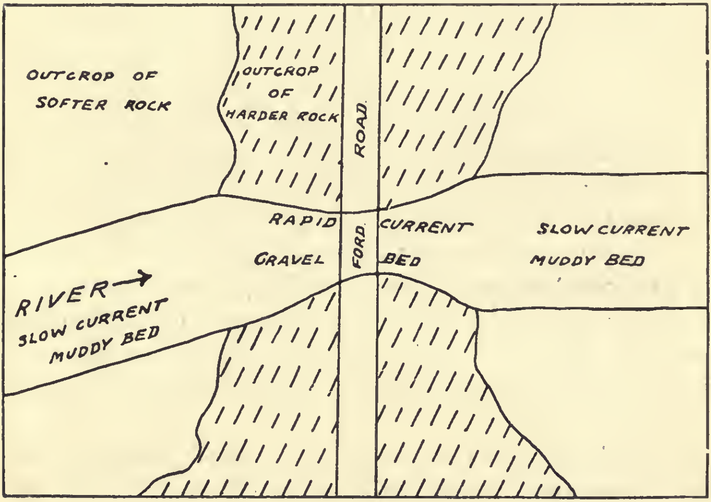

Fig. 73. Ford.

Many rivers form flood plains. These flood plains usually occur in the lower part of the river's course, but flood plains may be formed further up the river at places where the nature of the land surface has caused the river valley to be wide, and the velocity of the current slow. The Indus Valley in Kashmir is an example.

During floods, the river does not widen greatly in those parts of its course where the valley is deep and narrow, but where the valley is wide and shallow the river may overflow its banks and extend a great distance over the valley on either side. Such widening will prevent the velocity increasing to such a rate as it does higher up, where the valley is narrow. Consequently a large amount of the mud brought down will be deposited not only in the bed of the stream, but also on the floor of the valley on either side. In this way in course of time a more or less wide level floor may be built up on the floor of the valley, forming what is called a **Flood Plain** (Fig. 74).

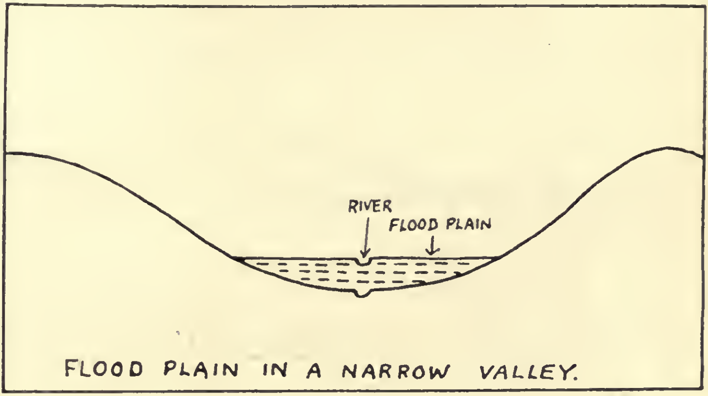

Fig. 74.

In the lower courses of many rivers the valley is exceedingly wide and shallow, and the flood plain of enormous width. In such places the deposition of sediment may actually raise the bed of the stream, and, the deposit on the banks being thrown down most abundantly nearest the river banks (Fig. 75), it happens that the stream flows between natural embankments at a level much higher than the general level of the flood plain. The Hoangho, the Po, and the Mississippi provide examples of such rivers. Exceptionally high floods in such rivers may cause the banks to give way, and the river may not only cause widespread destruction, but also change its course to a very great extent. The well-known changes which have occurred in the lower course of the Hoangho may be cited as an illustration.

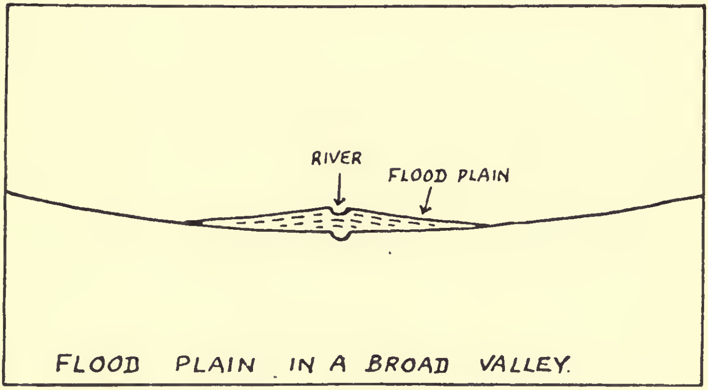

Fig. 75.

Needless to say, the inhabitants of such districts usually pay special attention to the preservation of such natural embankments (levées), which they strengthen artificially.

Again in such a flood plain a river very rarely pursues a straight course to the sea. It usually swings from side to side in large curves; for it is quite evident that a slight obstruction will cause a greater deflection in the course of a slowly moving stream over a gently inclined plain, than it will effect in the course of a stream flowing swiftly down a steep valley. River ports of a flood plain are often situated on "bluffs" overlooking the flood plain at a place where the river approaches its edge. Vicksburg and many other river ports on the Lower Mississippi are on such bluffs.

As the water flows around the curve the stream has a greater velocity around the concave bank than around the convex bank. Thus the concave bank will be undercut and steep while a deposit on the opposite side of the stream will cause the convex bank to shelve gently to the water (Fig. 76). And, in general, we find that materials worn from the undercut concave bank are deposited at the next convex part lower down on the same bank. The tendency is therefore for the course to become more winding, until whole loops are cut off.

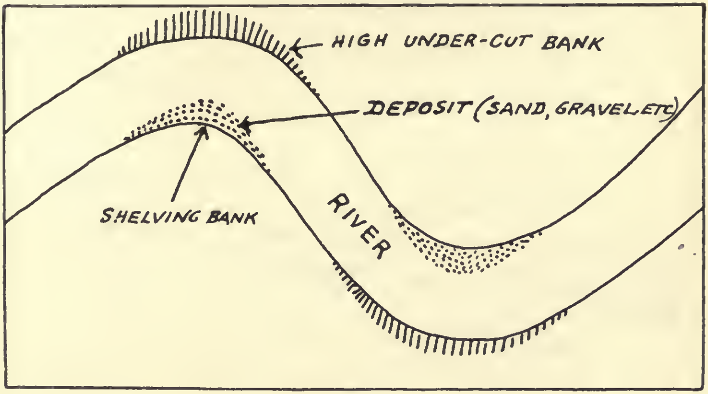

Fig. 76.

If the land is elevated, or if the rainfall is increased, the river may cut its bed deeper into the flood plain, and as it finds its new *lower* level, swinging from side to side, it cuts away the greater part of its old flood plain, and builds up a new one at a lower level. Often portions of the old flood plain are left high up on the sides of the valley. Such portions are known as **River Terraces.** A number of such terraces are often found at different heights on the sides of many valleys.

Formation of a Delta. When the river enters the sea, the velocity is very greatly reduced, and consequently mud and fine sand are deposited at the river mouth. This accumulation forms shoals, then mud flats, and later dry land, through which the river finds its way, usually by means of a number of streams. Such a delta may be of enormous area; that of the Ganges and Brahmaputra being more than 50,000 square miles, or about 1½ times the area of Ireland. Deltas are sometimes increased at a considerable rate. The "goosefoot" terminus of the Mississippi Delta is said to advance into the Gulf of Mexico at the rate of 100 yards per annum.

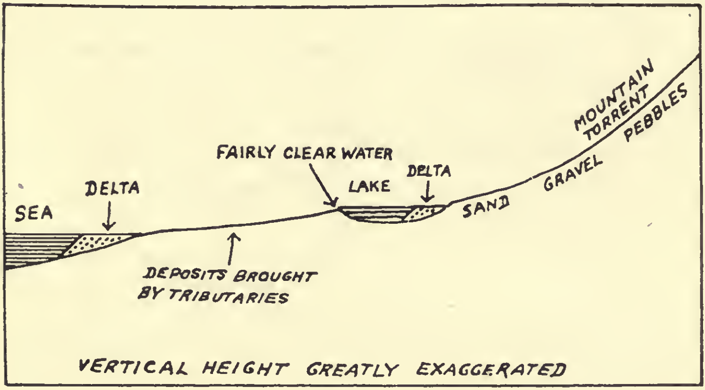

Fig. 77.

Deltas are often formed at the mouths of streams entering lakes, and many lakes are being filled by such deposits. Some of the alluvial deposits in a series of hollows along the courses of many Swiss streams are considered to be filled-up lakes. When a river flows through a lake, the lake renders the issuing stream clear

(Fig. 77). Thus the Rhone issuing from Lake Geneva is clear, while the stream entering the lake is turbid.

Fluviatile deposits upon flood plains and deltas are known as **alluvium.**

Marine Deposits. Detritus on the sea floor owes its movement to the sea being stirred up by waves and currents. The currents may be due to the tide, or an entering river; or they may be drift currents. In any case the deeper the water, the quieter it will be on the sea floor.

Detritus brought down by rivers is poured into the sea, where it mingles with the detritus formed by the wear and tear on the coast.

The particles are sorted out and arranged on the sea-floor in a definite order (Figs. 78 and 79).

(*a*) **Pebbles, Shingle, and Boulders** remain near high water mark, and may in fact be piled up during storms above the usual level of high water. The Chesil Bank, terminating in Portland, is a good example.

(*b*) **Sand** is found strewn over the beach, the coarsest sand being in the shallowest water, the finer sand being in deeper water further from high water mark.

(*c*) **Mud** is found further out than sand, and covers the sea floor in deeper and stiller water. The character of any individual beach depends upon many circumstances. The nature of the sediment brought down by rivers: the characters of the rocks composing the beach: currents formed by the set of the tides, etc., all help to determine whether the beach shall be covered with shingle, sand, or mud; and the configuration of the coast in the locality is usually more or less peculiar to itself.

Only the very finest sediment is usually carried further than 100 miles from the coast, while beyond 200 miles from the shore the sea bed never receives deposits formed by the wear and tear of land, except perhaps where large rivers like the Amazon cause strong currents outwards.

(*d*) **Limestone** is found practically pure on the sea bed, further out than mud. The limestone is made up of the remains of the skeletons of animals. These shells consist principally of calcium carbonate. In the deeper

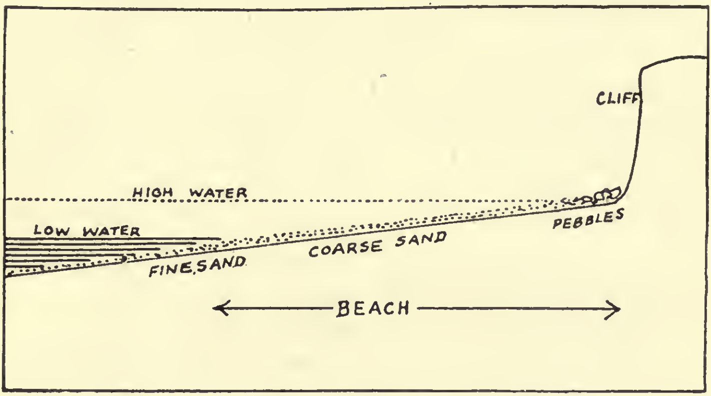

Fig. 78.

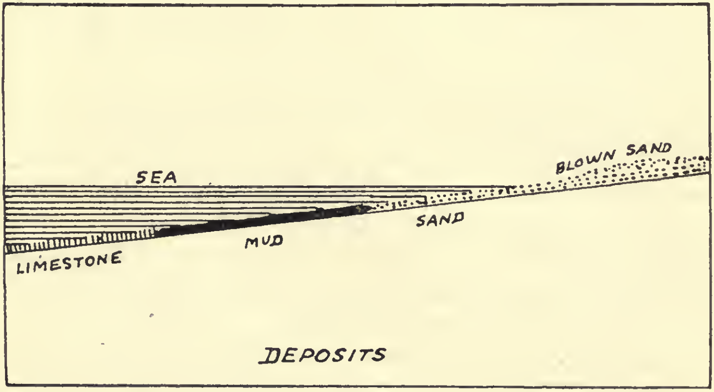

Fig. 79.

parts of the ocean the shells are dissolved before reaching the bed and in such places one does not find limestone deposits.

Limestones formed in shallower water consist of shells mixed with mud or sand.

Some beaches are covered with shelly sand, consisting largely of rounded particles of worn shells.

Coral often forms immense masses of limestones. It may also be broken up by the waves, and the particles strewn over the beach.

Stalagmites and stalactites are deposited when water containing large quantities of calcium carbonate evaporates. These deposits are common in limestone caverns on the seashore as well as in caverns further inland.

Blown Sand. At low tide a high sea breeze may dry the sand on the beach and blow it inland beyond high water mark. In this way are formed the sand dunes which are often found at the back of a sandy beach, where there are no high cliffs to prevent the sand being blown beyond high water mark. Sand dunes often advance inland, and sometimes cover fertile ground, rendering it useless. But they sometimes serve a useful purpose in forming a natural dyke preventing the sea from inundating a slowly sinking coastal plain. The delta of the Rhine is such a slowly sinking region, and the greater part of the Netherlands is preserved by artificially strengthened dykes.

Blown sand is often found in desert regions, and the loess deposits in China are usually thought to be due to the action of the wind.

Fossils. It will easily be understood that mingled with the deposits will be the remains of animals and plants which have died during the formation of the deposits.

Sea weeds, and shells, and hard parts of animals living in the sea, fall to the bottom and mingle with mud, sand, and limestone. Rivers also bring down the remains of dead plants and animals which have lived on the land.

Fossils are of very great use in unravelling the past history of the earth's crust. Concerning this, one or two facts must be noted.

1. In any series of rock strata it is found that each stratum has a characteristic set of fossils, which differ more or less widely from the fossils found in strata above and below.

2. Over a wide area the fossils of the same stratum are more or less identical.

Peculiarity of distribution, however, may account for differences of fossils in strata of the same age in different parts of the world.

3. Therefore strata can be arranged in order of time, when once the succession of fossils has been discovered in suitable regions.

4. The strata can be arranged in order, the oldest strata at the bottom, and the deposits formed at the present day at the top.

5. The general result is found to be :—

The older the stratum, the more widely will the fossils differ from the recent animals and plants, showing that living things have changed more or less during the deposition of the sedimentary rocks. This change is accounted for by the Theory of the Evolution of Species.

6. Fossils also enable us to obtain a very fair idea of the climatic and other conditions which obtained in the region, while the deposits containing the fossils were being laid down. Thus freshwater shells and the absence of sea shells will indicate deposits in fresh water, and large thin-leaved plants will indicate a warm moist climate.

CHAPTER XV

SEDIMENTARY ROCKS

Consolidation of Deposits. There are several ways in which deposits may be hardened to form rocks.

1. **Pressure.** A deep layer of sediment is able to exert considerable pressure on its lower layers. This pressure drives out the water and presses the particles, locking them together to form hard rock. In this way mud is hardened first to form clay. Then greater pressure renders it shaly; that is it begins to split into sheets or layers, which are at right angles to the direction of pressure. If the pressure upon the clay deposit is enormous, then the rock will be exceedingly hard and will split into very thin layers. Such a rock is called slate. Usually heat as well as pressure has helped to form the slate rock; moreover, the pressure may be exerted laterally. Most slates are more or less impure, from an admixture of sand or limestone.

2. **Cementing.** The water between the particles of a deposit usually contains matter dissolved in it. As the water slowly evaporates or loses carbon dioxide, these materials are separated out and, filling the spaces between the particles, cement them together. The chief cementing materials are calcium carbonate, oxide of iron, and silica.

3. **Heat.** An intrusion of molten material from the interior of the earth among the deposits often alters the character of the deposits. Thus marble is probably more or less pure limestone greatly modified by heat.

Some Common Sedimentary Rocks.

1. **Mud** is a fine deposit practically unaltered.

2. **Clay** of a more or less impure character is mud which has been altered by pressure and loss of water to

form a soft rock. Alluvial deposits, which have been raised above the sea level fairly recently, are often clays. The flats of Holderness and the fens are such rocks. When drained, the clay soils are stiff and fertile, and, where the summer temperature is sufficiently high, form rich wheat-growing regions.

3. **Slates and Shales** are rocks varying in hardness and in composition according to age and to the admixture of impurities, such as sand and limestone. The older and harder slates are usually highland regions with glen-like river valleys and high barren moors. The soil is thin and not of much use except for hill pasturage.

4. **Sandstones** consist principally of quartz grains united with some cementing material. Hard sandstones in horizontal strata often form pyramidal hills and vertical wall-like cliffs along the coasts.

Fairly pure sand gives a relatively barren soil covered with heaths, but when mixed with limestone it often forms a fertile soil.

5. **Limestones.**

(*a*) **Carboniferous Limestones** are hard rocks underlying the coal measures in the British Isles. They are not readily weathered, but are worn away rapidly by carbonated water. They form highland regions cut up into deep valleys. The valley floors are fertile, but the slopes and higher ground are covered with a very thin soil, forming desolate moors or sheep pastures.

(*b*) **Oolitic Limestones** consist of consolidated round particles of calcium carbonate. In England they form an oolitic escarpment, parts of which are known as the Cotswold Hills and Lincoln Heights.

(*c*) **Chalk** consists of the shells of foraminifera which were deposited in relatively deep, clear sea water. It forms escarpments with river gorges, and is usually a hilly country with softly rounded contours. The slope and the porous soil render it dry and covered with rather poor pasture given over to sheep farms.

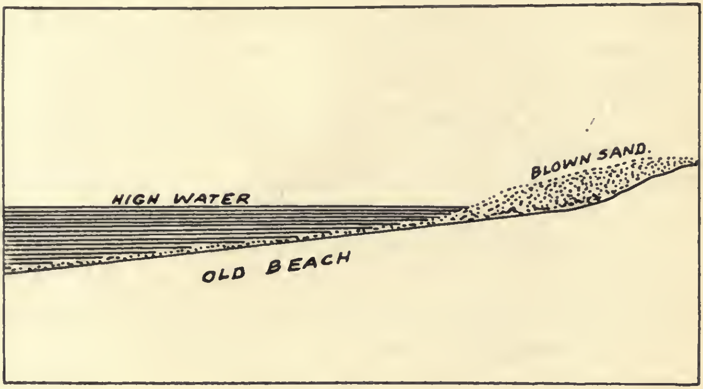

Fig. 80.

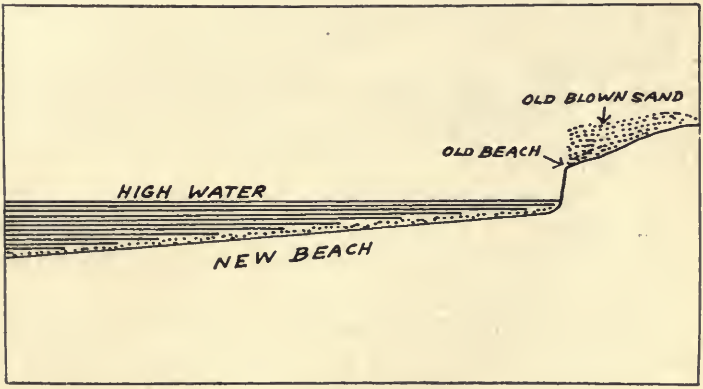

Fig. 81.

It must be remembered that the constitution of the soil depends not only on the underlying rocks, but also upon the deposits (drift) strewn over the land during glaciation. These deposits are often brought from a considerable distance.

Movements in the Earth's Crust. There are many evidences of the movements of the earth's crust.

1. **Fossils.** Fossil remains of marine animals are often found in strata thousands of feet above the sea level. They prove conclusively that the strata were deposited on the floor of a sea.

2. **Raised Beaches.** In many places around the coast are the relics of old beaches. These are often many feet above the present beach. Their present positions can be explained only on the assumption that the land once stood at a lower level (Figs. 80, 81). Along the east coast of Scotland is a narrow flat shelf at the back of which are the ancient cliffs. Along this shelf run roads and railways.

3. **Submerged Forests.** At many places along the coast are the relics of forests beneath the sea. In some places these old tree stumps are uncovered at low water, but elsewhere the sea never leaves them. Clearly the land stood higher when the forests grew than it does at the present day.

4. **Human Testimony.** Within historical times the changes in the level of buildings, and in marks made on the cliffs, show in some places elevation, and in other places depression of the coast.

5. **Fiords.** Fiords have doubtless been formed by the submergence of a highland region dissected by glens; in fact fiords are drowned river valleys.

Plane of Marine Erosion. From the sea level to some little distance below it the movements of the sea continually cause a wearing away of the coast, and, if no change of level occurred, the whole land surface would eventually be planed off, and the approximately level surface would be covered with shallow water. This is prevented from taking place by portions of the land rising and causing parts of the continental shelf to be exposed.

As soon as the continental shelf is exposed, rivers course over its surface, which becomes more and more uneven as the rivers deepen their valleys.

The continental shelf, including the lowland coastal plains, is the part of the land surface which has suffered most from marine erosion during geologically recent times.

At the present time the coast line is about half-way between the oceanic edge of the continental shelf and the inner edge of the lowland plain, the area of the lowlands being about equal to that of the submerged continental shelf.

Some Commonly Used Terms (Fig. 82).

Dip. When a stratum is inclined to the horizontal it is said to "dip." The direction in which it dips downward is given as N., S., S.W., etc.

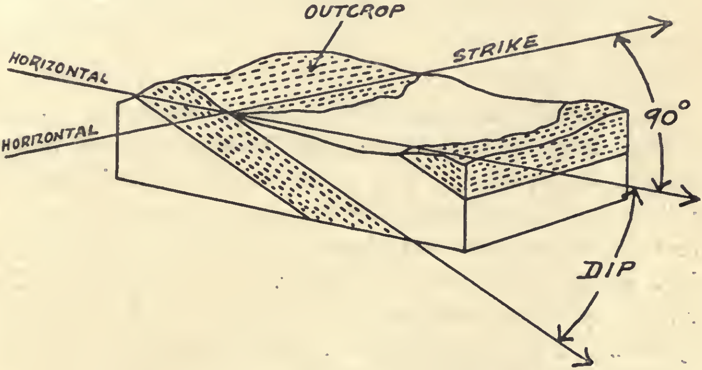

Fig. 82.

The angle of dip is the angle between the stratum and the horizon measured along the direction of dip.

Strike. The strike of a stratum is a horizontal line drawn at right angles to the direction of dip.

Outcrop. The outcrop of a stratum is its exposure on the surface of the earth. Its boundary would coincide with the strike only if the surface were horizontal.

Escarpment or Scarp. When a gently inclined stratum is exposed on the surface, it often happens that the outcrop forms a ridge of hills with a more or less gentle dip slope, while the opposite slope (scarp slope) is steep (Fig. 83). In England the Cotswolds, Edge Hill and Lincoln Heights are oolitic escarpments; the Marlborough Downs, Chiltern Hills, East Anglian Heights, Lincoln Wolds and Yorkshire Wolds are chalk escarpments.

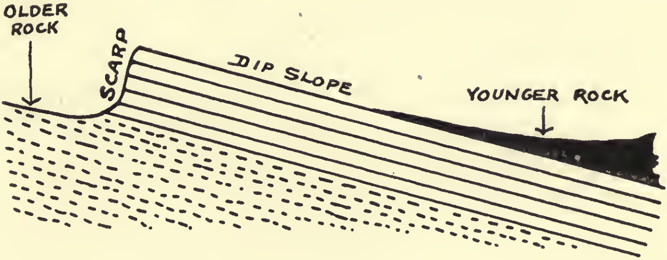

Fig. 83.

Longitudinal and Transverse Valleys. Many highland regions consist of parallel ranges with intervening longitudinal valleys. The course of the river is seen to follow the longitudinal valley for some distance, but, sooner or later, it bends at right angles, and passing through a gap in a range enters the next valley. In some regions the river may follow a zig-zag course across such a highland system. The Appalachian System, British Columbia, South-west Ireland, and South-east England provide excellent examples.

The following account refers to the more important points, but for full treatment Professor Davis' *Physiography* may be consulted.

Imagine a coast region which has been sinking for a considerable time, and note (Fig. 84):—

1. An almost flat continental shelf will be formed by the sea, while deposits will be strewn over it.

2. During this subsidence the inland region will be dissected into irregular river valleys, but if subsidence continues for a great length of time the destructive agencies of the atmosphere will render the highland region an almost level plain.

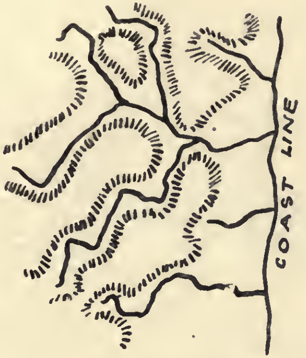

Fig. 84. Old land surface with very low relief.

Now imagine the land to rise slowly out of the sea (Fig. 85).

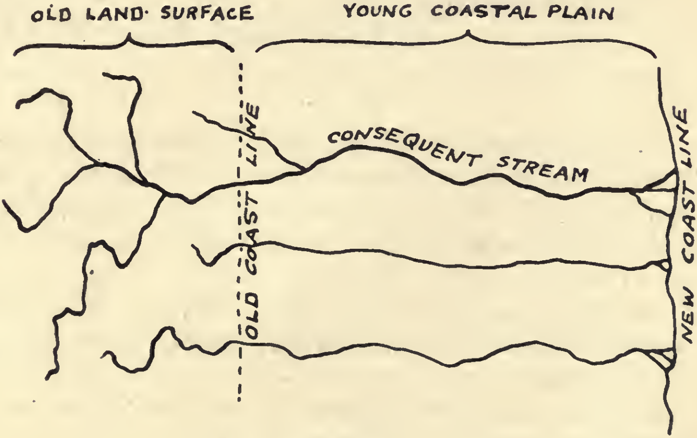

Fig. 85.

1. A low coastal plain of continually increasing extent will be formed.

2. The rivers from the old land surface will increase in length and flow across the gently shelving surface of the coastal plain to the new coast line. These rivers which are consequent on the elevation of the surface are termed consequent streams.

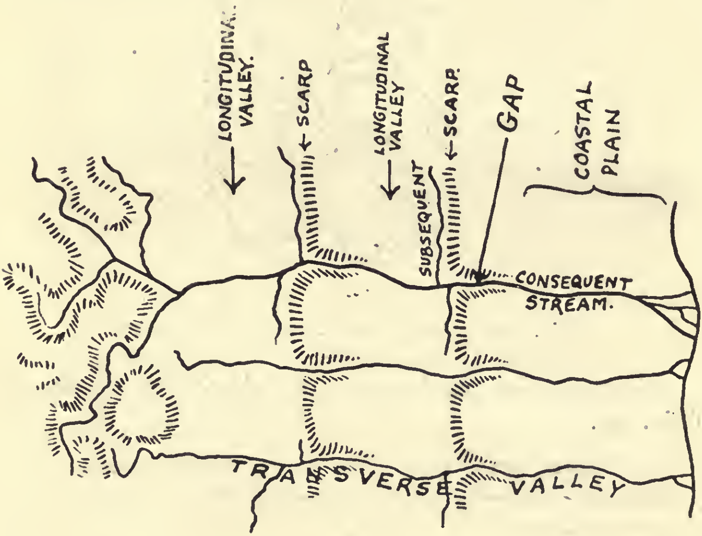

Fig. 86.

3. The exposed strata will dip gently towards the sea. Their strike will be approximately parallel to the coast line. Evidently the consequent rivers flow transversely across the strike. Consequent rivers may be termed transverse rivers.

4. The valleys trenched by the rivers across the recently exposed strata will be increasingly deep towards the interior.

Suppose now the strata are unlike in their capacities for resisting denudation (Figs. 86 and 87).

1. The outcrops of the harder strata will be left as a low range of hills, while the intervening softer strata will be worn away to form valleys, in which tributary streams will flow to join the transverse streams more or less at right angles.

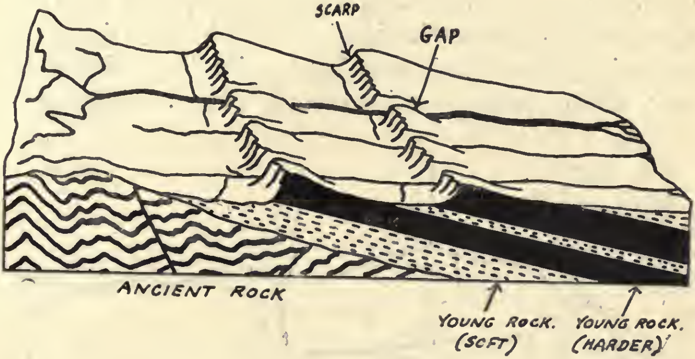

Fig. 87.

Professor Davis terms these later formed tributaries "subsequent" streams. As they flow approximately parallel to the strike, they may be called longitudinal streams. These longitudinal valleys will rapidly increase in width in the softer rock, and the rivers will increase in volume.

2. The low hills will present a gentle dip slope seawards, for débris is in an unstable position on the dip slope and will soon find its way to the river. The opposite slope will be steep, as the débris will be more stable on strata dipping into the hill. In this way a steep scarp facing inland is produced. In this respect it is instructive to compare the scarp and the dip slopes with the faces of cliffs dipping landwards and seawards respectively.

3. The longitudinal tributaries will tend to approximate more or less nearly to the foot of the escarpment,

but will receive most of their water from streams flowing down the dip slopes.

4. The transverse valleys will continue to cut their valleys through the harder strata in which river gorges will be formed.

In this way one may account for the gaps in the North and South Downs, in the Appalachians, and elsewhere. By such gaps communication is established, by river, road, and rail, between neighbouring longitudinal valleys, and hence towns naturally arise in such places. Guildford is one such town. A strong castle built on the hill overlooking the gorge served to protect, and sometimes to overawe, the townsmen below in many towns situated in such places.

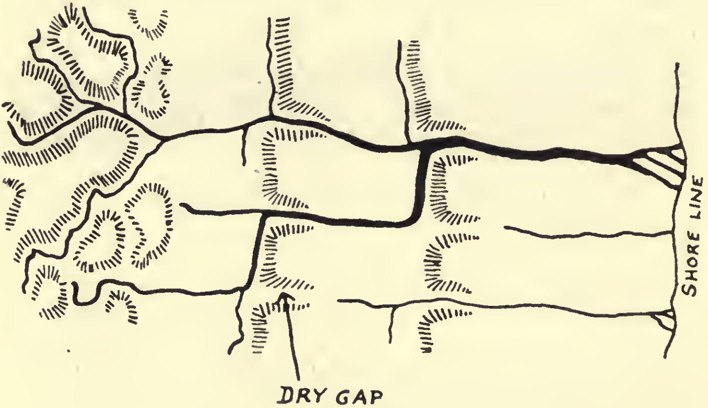

Fig. 88.

Where such a gap becomes filled with sea water, a large port may grow.

New York is one of the best examples of a port in a drowned gap.

5. The longitudinal tributaries of one stream may tap the streams of a smaller neighbouring valley, and in this way zig-zag rivers may be formed (Fig. 88).

The Thames above Oxford now takes the water from the upper courses of several streams which once flowed into the Kennet. The lower courses of these streams still flow into the Kennet from the north, but their volume is out of all proportion to the valleys along the floors of which they trickle.

In most regions varying capacities for resisting denudation, as well as contortion of the strata, conspire to obscure the longitudinal and transverse drainage system; and in a complicated group of mountains the rivers may flow radially from it, so that it is almost hopeless to expect completely to unravel its past history.

CHAPTER XVI

IGNEOUS ROCKS

IGNEOUS rocks are formed by the cooling of rocks from the molten condition. The first crust formed on the molten earth must therefore have consisted of igneous rocks. It is probable that none of the actual surface of the original igneous crust is preserved, even under any of the present deposits. It is clear that all sedimentary rocks were formed from the detritus produced by the wear and tear of igneous rocks, or of sedimentary rocks which had been formed from igneous rocks. Most of the materials forming the younger rocks have probably been used to form rocks over and over again during the many changes in the earth's crust.

Evidences of Internal Heat of the Earth.

1. Volcanoes eject steam, hot ashes, dust, lava, and hot gases.

2. In deep mines and borings the temperature increases with depth—to the extent of about 1° F. for every 60 feet

of increase in depth. At this rate at a depth of 50 miles everything known at the surface of the earth would be liquefied provided it was under atmospheric pressure only. But under the enormous pressure at a depth of 50 miles the materials are probably only potentially liquid.

3. Geysers and other hot springs eject water at a much higher temperature than that of the atmosphere.

Volcanoes. The volcano during its eruptions builds up a conical mountain from the materials ejected. These materials consist of large blocks torn from the sides of the pipe or vent, liquid particles, which, during their passage through the air, cool to form the so-called "bombs," ashes, and fine dust. The larger materials fall nearest the vent, the finer particles are distributed over a greater area, while some of the finest dust may be carried hundreds of miles away by winds. Then the molten lava wells over the lip of the crater and flows down the sides of the cone. Lavas vary in volume and fluidity, and while some streams are short and small in volume, others form sheets many square miles in area.

For our purpose the important parts of a volcano are the following (Fig. 89) :—

1. Reservoir of molten matter deep in the crust of the earth.

2. Pipe of the volcano leading upwards to the vent in the bottom of the crater.

3. Subsidiary fissures leading from the pipe, and penetrating the cone and underlying rocks in different directions.

In an extinct volcano the pipe is filled with solidified matter. The subsidiary fissures are also filled with similar material, and some also forces its way between the different strata; these last are known as sills. The more or less vertical sheets of solidified material which have entered fissures form dykes. These rocks are often harder, and resist wear and tear better, than the strata among which they are intruded, and often form conspicuous features in the landscape.

One often finds that ancient volcanoes have been worn completely away except for the stump of solidified matter in the pipe. Many hills in North Wales are such ancient stumps, the cones having disappeared.

Plutonic Rocks. Some of the molten rock deep down in the earth, or in the reservoir beneath a volcanic pipe, cooled very slowly, and in consequence all its constituents are crystalline in structure, while lavas are often glassy and non-crystalline.

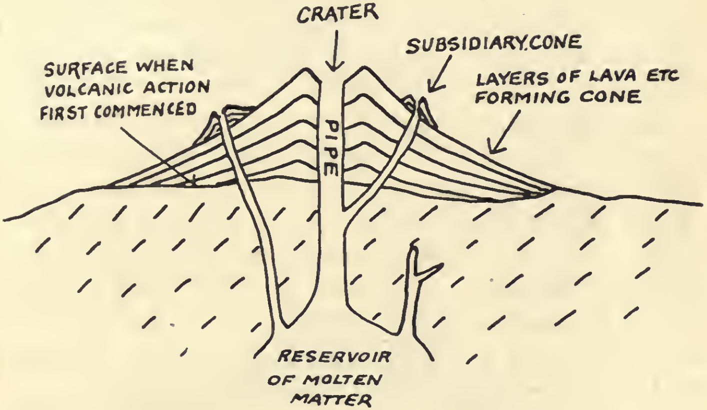
CRATER
SUBSIDIARY CONE
SURFACE WHEN VOLCANIC ACTION FIRST COMMENCED
LAYERS OF LAVA ETC FORMING CONE
PIPE
RESERVOIR OF MOLTEN MATTER

Fig. 89.

These molten masses would penetrate the fissures of surrounding rocks and might even form extensive sheets between their layers. Such filled fissures of all sizes are seen around granite masses in many districts.

Granite may be taken as a type of such rock which has cooled slowly. It is interesting to note that in the rocks surrounding granite masses are usually lavas or other evidences of volcanic action, and such granite masses may be considered as material cooled in the reservoir beneath a volcanic area. The granite moors of Cornwall and Devon are said to have been solidified under at least 5 miles of overlying rocks.

Metamorphic Rocks. Many rocks which were originally sedimentary, and many which were volcanic or plutonic, have been profoundly altered by heat and water, or by both, so that many sedimentary rocks have been rendered more or less crystalline. Slate, marble, gneiss, and schist are examples.

The heat is derived from intrusive sheets of molten materials or is produced by pressure during contortion. The smaller sheets have relatively little effect on the rocks on either side, but very large masses of granite have often modified the surrounding rocks for a distance of a mile or more.

Mountains. The great mountain ranges of the earth have been formed where bending and crumpling of the earth's crust has been most extensive. We find, as we might expect, that volcanoes are associated with these folds. It appears that the overlying solid materials constituting mountains are raised by the pressure of the underlying molten matter. Molten rock finds its way into the fissures formed when the rocks are crumpled and bent.

Most mountain ranges have been formed by the many uplifts which have occurred during the earth's history, and consequently such mountain ranges show a very complicated structure, sedimentary, volcanic, metamorphic and plutonic rocks existing in apparent confusion.

In old ranges, where denudation has been extensive, most of the overlying rocks have been removed, and the worn down range consists of the solidified plutonic core of crystalline rocks (Figs. 90 and 91).

Some of the younger ranges, such as the Pennine Range, are comparatively simple arches which have not been sufficiently denuded to expose the underlying crystalline cores.

The importance of mountains :—

1. They exert a great influence upon climate : if at right angles to a prevailing moist wind their seaward slope is one of great rainfall, while on their landward side is a dry rain-shadow region.

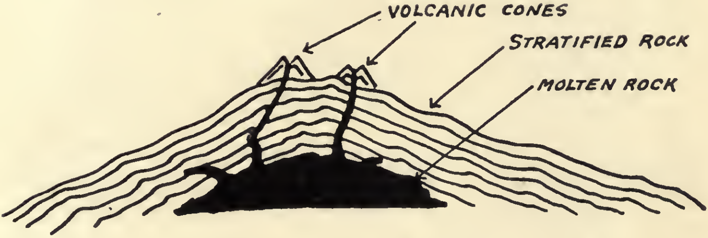

Fig. 90. Young Mountains.

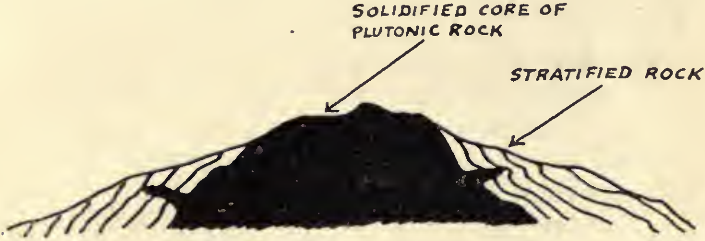

Fig. 91. Old Mountain.

2. They may shelter a region from cold winds or shut out warm winds.

3. Elevation may cause a climate to be much cooler than one would expect from the latitude.

4. They form well-marked, and sometimes impassable, barriers between nations. This may make for peace and security, but it may also restrict commercial intercourse, and by isolating nations prevent intellectual progress.

5. The wet side of a mountain is covered with forests, the dry side with sheep pastures.

6. The mountains are a source of water, and in regions where the rainfall is unevenly distributed throughout the year they may keep the rivers full even in dry seasons by the melting of snow.

7. The falling water in mountainous districts provides a source of power which can be used to drive machinery; in former days water wheels, in modern times dynamos for electric power.

In some regions there is a more or less distinct **Fall Line**, where the coastal plain comes to the foot of the highlands. Along this line are falls near which towns are situated. Such a fall line is found on the eastern edge of the Appalachians.

8. Mineral wealth is usually associated with the bent and faulted rocks of mountain regions. The excessive denudation has exposed veins of valuable minerals, which were probably formed at a great depth below the surface of the earth.

Building Materials, etc.

1. **Building Stones.**

(*a*) **Limestones.** Of these the best known are the Oolitic Freestone and Magnesian Limestone.

(*b*) **Sandstones.**

(*c*) **Roofing Slates** are obtained from the older Primary Rocks, the best being found in North Wales.

(*d*) **Granite,** though commonly used in some districts, is not in general use throughout the country.

(*e*) **Marble and Serpentine** are ornamental stones.

2. **Clay.** Many of the clays of the eastern districts are used for brick and tile making.

Fire clays are found in carboniferous rocks underlying the coal seams. They owe their property of resisting great heat to the absence of alkalis which have been removed by the ancient vegetation growing on them.

In Devon and Cornwall the finer clay—**kaolin**—formed from the granite by weathering is used for the making of porcelain and china.

3. **Flagstones** are obtained from the sandstones of Scotland and the carboniferous rocks of Yorkshire. They split into thick slabs.

4. **Lime** is obtained by heating chalk and other limestones.

5. **Clay Limestones**, when heated, produce hydraulic cements.

6. **Millstones and Grindstones** are made from the grits and sandstones underlying the coal measures.

7. **Salt**, chiefly found in triassic rocks, was formed by the evaporation of inland seas or lakes. Its occurrence near coalfields in Cheshire and Durham accounts for the manufacture of soda, glass, soap, and chemicals in those places or near them.

CHAPTER XVII

MINERALS

Faults in Rocks. When we examine any old rocks which have been contorted, we notice that they are full of cracks. These cracks are known as **faults**, and it is evident that such faults will allow the rocks on one side to be moved to a different level. Thus in the Great Basin of the Western States of North America more or less vertical faults in horizontal strata have allowed plateau-like crust blocks to be formed from the sinking down of the strata beyond the faults on the other side (Fig. 92). The crumpling of strata is usually associated with faults traversing the rocks in all directions.

If the fault is not in one plane, the slipping of one side over the other will cause the fault to open. Into these faults, which may extend to very great depths in the earth, various liquid substances may be injected. The solidified matter in these faults is termed a vein (Figs. 93 and 94).

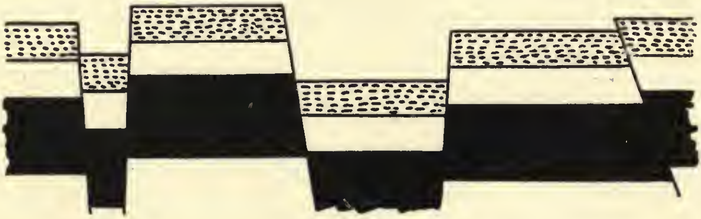

Fig. 92.

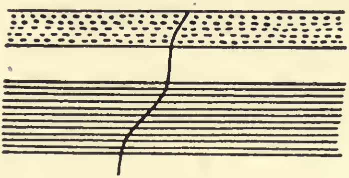

Fig. 93.

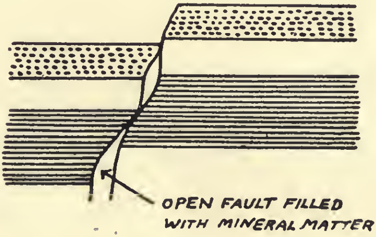

Fig. 94.

At great depths the temperature of water in the rocks may be very high, and water at a great temperature and under a heavy pressure is able to dissolve substances which at the earth's surface or at a low temperature are practically insoluble. When such water enters a fault it may deposit mineral matter as it cools, but in most cases it is probable that more or less complicated chemical changes occur among the materials filling the fault. At any rate the result is that the fault becomes filled with mineral matter. In many dark slate rocks milky quartz veins are very conspicuous. The veins are of varying thicknesses, some being as thin as writing-paper, while others are several feet thick.

Most of the minerals found in these veins are of no economic importance, but others are compounds or **ores** of valuable **metals.**

Occasionally these veins come to the surface of the earth, but a large number of them are covered up either by younger rocks or by a layer of soil and subsoil.

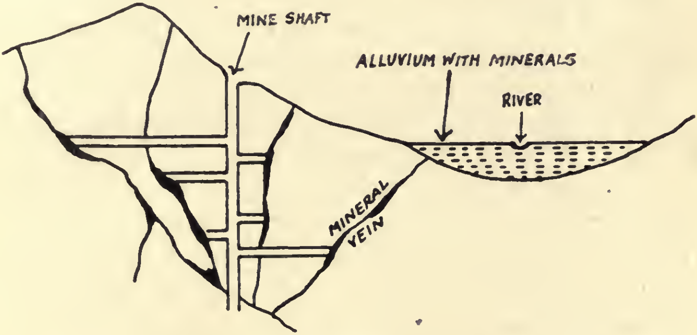

Fig. 95.

Minerals in Alluvium. In districts where the old rocks containing minerals have been exposed and carved out by rivers, the ruins of the rock and mineral veins will have been washed down into the river valleys, and the heavier particles of mineral matter will form a sediment in the river bed or its flood plain, while the lighter particles will be carried away. In this way, in course of time, a considerable quantity of ore, or even the pure metals (native metals) themselves, may collect in the alluvial deposits formed by river action (Fig. 95).

By digging in the alluvial plain, or by taking mud from the river bed and washing it, the heavier metals or their ores can be separated. In this way copper and gold are obtained in many regions.

But in course of time this supply, which is never very great, becomes exhausted, and then it is necessary to sink shafts into the solid rocks to obtain ores from the veins.

In primitive times only the first plan could be adopted, and we find that copper and gold are the oldest known metals, and that the copper and bronze ages preceded the iron age.

Mining Regions. In studying the mineral-producing regions it is important to remember that minerals are usually found in the veins of the older rocks. In many parts of the world these are covered up by thousands of feet of younger rocks so that the expense of working would be too great to render it profitable.

Minerals can be obtained most cheaply from the older rocks, which have been raised by earth movements and laid bare of younger rock by the action of the atmospheric agents and by river action. Such regions are usually highland regions.

Some Important Minerals.

1. **Iron.** Any rock containing sufficient iron to render it profitable to smelt is called ironstone.

(*a*) **Clay Ironstone** consists of clay containing carbonate of iron, which has been precipitated from solution. It is often found in layers or as nodules around plant remains, which form a nucleus about which the deposition of the iron compound has occurred. This is the usual iron ore found in the coal measures.

(*b*) **Sandy Ironstone** consists of sand and oxide of iron, the latter being probably derived from the carbonate.

(*c*) **Iron Limestone** consists of limestone and iron carbonate, large portions of the latter often being converted into iron oxide. The surface layers of this rock are rusty in colour. This iron ore is found in the oolitic limestones in England.

(*d*) **Hæmatite** generally occurs in limestones. It is an oxide. Pilots Knob, a mountain in the State of Missouri, is an immense mass of hæmatite.

(*e*) **Magnetite** sometimes forms the substance of whole mountains. It is an oxide.

As both iron ore and coal are bulky in proportion to their value, the less valuable ores such as clay ironstone are only smelted when obtained near a supply of coal. The more valuable ores, hæmatite and magnetite, are often worth carrying some distance. They are usually brought to coalfields which are situated on the sea coast. Thus ores are brought from Bilbao in the north of Spain and smelted at Swansea. In Pennsylvania and Ohio natural gas is the fuel used for smelting.

In the smelting of iron, limestone is used as a flux, and gannister for lining the furnaces. These are obtained on most of our coalfields.

2. **Copper.** Copper is found native in many parts of the world but in largest quantity in the neighbourhood of Lake Superior.

The chief ores are the red and black oxides, carbonate, and copper pyrites.

Ores from all parts of the world are smelted at Swansea.

3. **Lead.** Galena—lead sulphide—is the chief ore.

4. **Tin.** Cassiterite—an oxide—is the only ore. Large quantities are obtained from the Malay States and smelted at Swansea, giving rise to the tin-plate industry. Tin-mining is an important industry in Cornwall.

5. **Zinc.** The chief ores are zinc blende (a sulphide), a red oxide, and calamine (zinc carbonate).

6. **Aluminium.** Aluminium is obtained from cyrolite by electrolysis. Consequently it is extracted near waterfalls, where water power drives the dynamos—(Niagara Falls, Schaffhausen, and Fall of Foyers).

7. **Gold.** Gold is obtained from alluvial deposits, but a considerable amount is derived from quartz veins. The auriferous quartz is crushed or stamped to powder, and the gold extracted by the aid of mercury.

8. **Mercury.** Mercury is found free and in union with gold and silver, but cinnabar, its sulphide, is the chief source of the metal.

9. **Silver.** Silver is sometimes found free, as well as in the form of many different ores. It is often associated with lead ores in such quantities that separation is profitable. Mexico and the United States are the chief silver-producing regions.

10. **Platinum.** Platinum is a relatively rare infusible metal, always found free or alloyed with some of the rarer metals in alluvial deposits, principally in the Ural Mountains.

CHAPTER XVIII

COAL

Formation. A coal seam usually rests upon a clay seam—the **under-clay.** Roots of erect plants are found penetrating the under-clay. The under-clay represents the soil of the delta or low swampy coast which was covered with dense vegetation. As generations of these plants lived and died, their remains would form a thick layer. It is this mineralised vegetable matter which constitutes a coal seam. If the surface of the swampy soil on which the forest grew slowly subsided, a coal seam of considerable thickness would be formed. Above the coal seam is usually a roof of sandstone.

The following are the commoner types of coal :—

1. **Lignite** is wood slightly mineralised. It contains about 25 per cent. of oxygen.

2. **Cannel Coal** contains about 10 per cent. of oxygen, and is so rich in gases that it will kindle at the candle flame. It is useful for gas-making.

3. **Bituminous or House Coal** contains about 7 per cent. of oxygen. It burns with a smoky flame and is fairly rich in gases.

4. **Anthracite** is a very hard coal, with less than 3 per cent. of oxygen, and little or no combustible gases. It is useless for gas-making and burns with a hot smokeless glow. It is more or less completely mineralised coal, which has been altered by great pressure and perhaps heat.

Mineral Oil (Petroleum). Petroleum is generally considered to have been formed by the natural distillation of organic remains in the rocks. It is often found in strata far removed from the rocks where it was formed, as it is able to travel along fissures and soak into porous rocks. In some places it rises to the surface in the same way that water rises in artesian springs.

Some shales yield oil on distillation. These shales are called **oil shales.**

The crude mineral oil varies in consistency from a thin liquid to a viscid substance like a tarry liquid. It consists of a variety of paraffins, of which paraffin oil, vaseline, and paraffin wax are common examples.

Natural Gas. The gases given off from the vegetable matter during mineralisation find their way into the pores and fissures of the surrounding rocks.

Deep in the rocks the pressure is great, and the gas is compressed. On being tapped, large supplies of natural gas are readily obtained.

Peat. Peat consists principally of parts of moss plants which grow on the boggy shores of lakes. As the lake is slowly filled with mud, the moss covers it. The mosses die and other generations of mosses grow upon their remains. The acid water of such places prevents decay, so that the peat consists of dead mosses and other bog plants very slightly altered, only a small amount of the gases being lost from the carbonaceous matter. Peat is generally formed in the hollows above more or less impervious rock, such as upon granite moors, and on the horizontal limestone strata of Central Ireland.

Industries on Coalfields.

1. **Iron Manufacture.** Where coal and iron are found close together, especially if limestone and gannister occur in the district, iron smelting and the manufacture of iron goods will be carried on.

2. **Coal and Iron near Coast.** There will probably be a large quantity of coal exported, iron smelting will be carried on, and steamships will be built.

3. **Coalfield within easy reach of Ports.** The industry carried on will depend very largely on the nature of the raw material which can be imported. In such a region raw material of large bulk and low cost can be imported cheaply, and therefore manufactured articles of large bulk and low price, which entail relatively little labour, can be produced. Lancashire and Yorkshire possess such coalfields. Other conditions may also be important: thus the hygrometric condition of the atmosphere in Lancashire is suited to cotton manufacture, while such is not the case on the drier eastern side of the Pennines.

4. **Coalfield far from the Sea.** A raw material, by the time it has reached the coalfield, will become expensive,

and on this account the articles manufactured will be those which demand the expenditure of a large amount of labour upon a comparatively small amount of raw material. Thus in the Birmingham district watches and cycles are manufactured.

CHAPTER XIX

DENSITY OF POPULATION

In any district the density of the population will be found to depend upon the following factors:—

1. **Supply of Food.** In such countries as China and India, where there is an abundance of rain and great heat, the vegetation is luxuriant, and hence the soil can easily be made to yield enormous crops of food products.

Moreover in these warm regions food is not required to supply heat to the body, therefore, compared with people living further north, the people of South-east Asia require relatively little food, and, as food is abundant in these regions, it follows that a teeming population can be supported (Fig. 96).

A similar cause accounts for the dense population of Egypt, where the irrigating power of the Nile does for the soil what the scanty rainfall cannot do.

Further north, where vegetation is very scarce, the people depend upon animal food. Moreover in such cold regions food is needed to supply heat to the body. Hence a relatively large amount of food is needed, whereas at the same time food is scarce. Thus such a region will support only a sparse population.

Deserts, unless they produce great mineral wealth, are almost uninhabited. Labrador, a cold desert, and parts of the Sahara, a hot desert, are examples.

2. **Mineral or other Wealth.** Many regions which cannot produce sufficient food to supply a large population can produce some form of wealth which it can exchange for food.

Where coal or valuable minerals are found, the district will support a number of people, who work in the mines, or carry on manufactures near them. The products are exchanged for food and other necessities.

Coalfields usually support a dense population, for not only do they attract miners, but they also attract manufacturers, who need coal to drive the machinery.

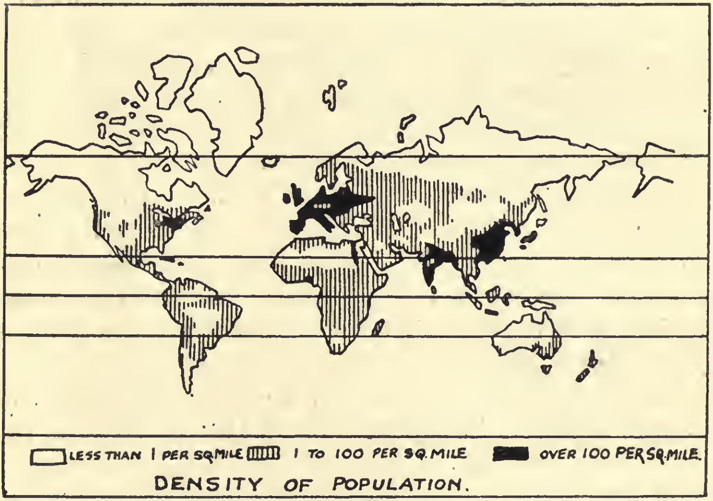

Fig. 96.

Europe has a naturally fertile soil, and even if it had no mineral wealth it would support a fairly dense population. But in addition to possessing a fertile soil and an excellent climate, many parts of Europe possess valuable mines, and it is in such regions that we find the densest population.

The rushes to Australia, California, and Alaska show how mineral wealth attracts people.

3. **Intelligence of the People.** The amount of wealth, both vegetable and mineral, which people can obtain from the earth, depends partly upon the intelligence of the people. North America illustrates this. The Aborigines of North America used few or no metals, and carried on agriculture in a very primitive fashion. In fact many of them lived more by hunting than by tilling the soil. Thus the native population was never dense. But since white men have settled in America the population has enormously increased, for the more intelligent European has made the rocks give up their coal, iron, gold, and silver and, what is of still greater importance, he has applied better methods to agriculture. Hence we find that the present population, which is increasing rapidly, is out of all proportion to the aboriginal population.

4. **Health of a Region.** An unhealthy region will be inhabited only by those people who have acquired immunity against the prevalent diseases of that region. In many regions of dense tropical forests the natives are unintelligent and unable to develop the natural resources. The unhealthy nature of the regions keeps away immigrants, and thus such regions support only a very scanty population. But, as time goes on, the progress of medical science enables man to fight these diseases more and more successfully, so that regions like the Congo and Amazon Basins will be rendered accessible to the more intelligent people from other regions.

The Panama Canal illustrates this fact, for the work was abandoned principally on account of the very unhealthy nature of the climate. The progress of medical science has enabled the labourers to work on the Canal, and the final success of the scheme is due as much to the doctor as to the engineer.

CHAPTER XX

OCCUPATIONS

PRIMITIVE man, living in tropical or warm temperate forest regions, found fruit ready at hand throughout the year, and, as he needed no clothes, there was not any very great demand upon his intelligence. Consequently he made little intellectual progress so long as he remained in such regions. Even to-day the natives of dense tropical forests are in a very low stage, while the Australian, who has been isolated from the rest of the world from very early times, is scarcely human. Moreover, he had no milk-giving animal to domesticate and no grass to cultivate and produce grain, so that his low condition occasions no wonder on our part.

Hunting. As primitive men spread out from their tropical homelands, they found food more and more scarce, and also felt the need for clothing. Moreover, the lower temperature in higher latitudes created a desire for more heat-giving food. Food was less abundant though more was needed, so that man's intelligence was taxed to a far greater extent, and in this way by slow degrees man advanced above a condition of savagery and became a hunter, eking out an irregular vegetable diet with the flesh of animals caught in the chase. In the coldest regions man's food was wholly the flesh of animals. Primitive clothing was undoubtedly made from the skins of slaughtered animals.

The nature of his occupation makes the hunter lead a lonely life, and, in fact, every hunter is of necessity his neighbour's enemy ; and though hunting cultivates the faculties of observation and reasoning and develops inventive ability, yet it is an occupation rather antagonistic to those social ideas which are essential to higher civilization.

At the present time there are of course no hunters in this purely primitive stage, but the Australian Blacks, and the Eskimo in a lesser degree, illustrate the influence of hunting upon the lives of people. Even the white trapper, who haunts the cold forests of the New World, is a lonely and more or less uncivilized person.

Fishing. River fishing is merely a variety of hunting, and induces characteristics in man very similar to those developed by other forms of hunting, but sea fishing brings him into contact with new dangers and acquaints him with new ideas.

In modern times fishing is carried on with complicated implements, while ice chambers and fast steamships enable fishermen to work in waters far from their markets.

Fishing grounds are found where fish are abundant, where they are near fishermen's homes, and where the grounds are within easy access of markets. The principal fishing grounds are the shallow seas off the north-west of Europe, the banks off the east of America, and the shallow regions of the North-west Pacific.

Pasturing. Hunting slowly gave place to pastoral and agricultural pursuits. A hunter's existence is always precarious, and starvation is an ever-present danger. Consequently, where the region was suitable, some animals would be domesticated—especially milk-giving animals—and the commoner food plants cultivated against a time when game would be scarce. In this way, with many people, hunting would be given up gradually and replaced by the shepherding of flocks and the growth of food plants. The shepherd's occupation would be followed by the inhabitants of grassy plains and hill sides where the rainfall was too scanty for agriculture.

The hunter-shepherd people would be nomadic, living in tents, and even a shepherd people would be nomadic in regions where the grass would not be rich and green throughout the year, for they would be compelled to drive their flocks and herds from place to place in search of pasture.

The mental condition of pastoral people is much in advance of that of hunters. The hunter, having few or no possessions, has no fear of robbery, but the shepherd is in perpetual danger of losing his flocks, not only by marauding animals, but also by robbers. This compels pastoral people to unite in self-defence and gives rise to a tribal system, in which the ties are far firmer than among hunters. With the growth of the tribe arise the social virtues—consideration for others, faithfulness and generosity; as well as social vices—the lust of power, and vanity, and also rough distinctions of class.

Even to-day many nomadic pastoral tribes are found wandering over the wide grassy plains.

In modern times immense ranches and sheep runs have grown up in the New World, South Africa, and Australia.

Agriculture. The primitive hunters would not only become shepherds, but would also cultivate the soil, at first only to a small extent in spots where they settled for a season, but later on, in suitable surroundings, they might even leave hunting completely, and carry on a mixed agricultural and pastoral life. In some places agriculture would be the only occupation carried on.

Agriculture is a more skilful occupation than shepherding, requiring a higher degree of intelligence.

The regions best suited to agriculture are the river valleys and coastal plains of the warmer parts of the world, and especially places where the periodical flooding of the river covers the surface of the plain with a fertilising silt.

It is in such regions that the early civilizations grew up. Egypt, Mesopotamia, Hindustan, China are very similar in general characters. Moreover, they were shut in by deserts or high mountains, which lessened the chances of invasion. In these regions a dense population grew up. An agricultural population is peace-loving and long-suffering, for the fertile soil allows of a large accumulation of wealth which tempts invaders, who, if successful, become despots and grind the uttermost farthing out of the conquered, while the native rulers of such agricultural people are not less exacting.

Towns originated in the first instance as fortified places for the agricultural population. The open plains, in which agricultural populations grew up, were quite open to attack, so that fortified places, into which the people could withdraw, became a necessity. Such towns were situated on hill tops, or at the bend or confluence of rivers where they could most easily be defended. Later on the town would become a centre for trade. Most towns in modern times are industrial or trading centres, modern conditions of warfare rendering the number of fortified towns fewer and fewer in proportion as time goes on.

In most regions where early civilizations were evolved, the seasons are well marked off, and the orderly variations in natural phenomena no doubt had considerable influence in directing men's minds to the study of causes—to religion and philosophy.

Lumbering. Trees were of importance for building purposes and fuel even in early times, and at the present time two-thirds of the timber felled is used for fuel. Increasing quantities are required for a great variety of uses, of which paper-making is one of the most modern, large quantities of timber being converted into a pulp for that purpose.

On account of its large bulk timber is not cut in large quantities except near rivers along which it can float down to the sea.

Mining. Mining is the youngest of the great industries.

Coal and iron mining are the most important, as they provide both machinery and the power for working it, enabling manufactures to be carried on.

The use of fire and the ability to make implements from metals (bronze, iron and steel) were important factors in man's progress from barbarism to civilization.

Manufactures. In the earliest stages of human culture " home industries," principally carried on by women, were the only " manufactures," and even in comparatively late times manufactures were not confined to definite areas, but carried on all over the country principally by hand labour, but also by simple machinery driven by water power or windmills.

The use of water power caused mills to be situated close to waterfalls or on quickly flowing streams, many of which were dammed up for that special purpose. When rivers were canalized, mills were often built close to the weirs.

The use of steam engines to drive machinery caused manufacturers to migrate to the coal fields, where the supply of fuel is abundant. The change thus brought about, the rise of the present factory system of modern industrialism, the congestion of the " hands " in badly built towns, and the growth of slums, with many other drawbacks and evils, present to us the spectacle of an enormous increase of total wealth together with the rise of evils which are a positive danger to civilization. This " industrial revolution," which began in the eighteenth century, provides many serious problems which civilization has scarcely yet attempted to solve.

Trade and Transport. Trade is the exchange of commodities. In primitive society it was carried on by barter, but in modern times money is the medium of exchange.

Trade is caused by the fact that different regions produce different commodities, while no more or less restricted region produces all the commodities which the inhabitants of that region need. But the surplus commodities they produce enable them to exchange those commodities for produce from different regions.

The ideal condition of affairs is reached when each region produces those commodities for which it is naturally suited. Governments, however, put various restrictions upon production and trade, some of which are good, but others of which are bad.

The following are some of the most important means of transport :—

1. **Human Porters.** This method of transport is employed only where the cost of labour is low and where the roads are bad. Moreover, it is restricted to warm regions and to people of low intelligence, because the former condition permits labourers to live on a small amount of food, while the latter renders the standard of comfort low. Human porters are employed in tropical Africa and in the south-east of Asia and China.

2. **Wheelbarrows** are not commonly used outside of China, where the roads are bad and human labour cheap.

3. **Pack Animals.** In many parts of the world it is either difficult to construct roads, or the people lack sufficient enterprise or intelligence to construct them. Countries recently developed by civilized people often possess bad roads. The South American Republics are such places, while Spain, Italy, the Balkan Peninsula, and Asia Minor are rugged and lack good roads. In such places the roads are usually rough narrow tracks with very steep gradients.

This permits of the employment of sure-footed animals only.

(*a*) **The Ass** is used in regions where the country is rough, but where the roads are not steep.

(*b*) **The Mule** is far hardier, more sure-footed, and stronger than the ass, and is the most generally employed pack animal in very hilly or mountain regions, as in Mexico, Central America, and the South American Republics.

(*c*) **The Llama,** a relative of the camel, is employed in certain parts of the Andes.

(*d*) **The Yak** is a kind of goat used in Kashmir and Tibet.

(*e*) **The Horse** is not so sure-footed as the above-mentioned animals, but is swifter, and is the most useful pack animal in lowland regions, especially on grassy plains, such as the steppes of Eurasia and great plains of North America.

(*f*) **The Camel** is especially adapted for desert life. Its widely expanded foot prevents it sinking in the sand, the humps on its back act as storehouses for food, so that it can go without food for a considerable time, while in its stomach are reservoirs for water storage. These characters enable it to endure long fatiguing marches across desert sands.

4. **Carts and Waggons** can be used where roads are sufficiently wide and fairly good, or where the ground is more or less even, as on the steppes and prairies. Consequently this means of transport is only used on the lowlands of countries where the people have been civilized for a considerable time, as in Europe and India, or on grassy plains, as on the prairies or on the veldt.

The carts and waggons are drawn by horses, mules, asses, oxen, and sometimes even by dogs.

In cold regions sledges are used and are drawn by horses or reindeer or dogs.

5. **Rivers and Canals.** The rivers of a country often provide an excellent and cheap means of transport, unless they are too rapid. Even then rivers are useful for floating timber down from the forest, and as a source

of power. The most useful rivers are those of lowland regions, especially where the volume of the river is not liable to great or sudden variations. Most of the lowland regions of the world provide examples of excellent river systems, and in civilized countries the system has been improved and extended by construction of canals and the canalization of the rivers. The earlier trade routes of most countries, except desert regions, followed the courses of rivers.

Barges towed by horses or mules are used on the smaller canals. On larger rivers sailing-vessels, or even large steamers (e.g. cotton steamers of the Mississippi), may be used.

6. **Coasting Trade.** This was exceedingly important before the advent of railways, and even at the present time it is large in amount on account of cheapness in comparison with railway freights. A large number of wooden schooners are engaged in this trade, but an increasing number of steamers are now being employed, especially for perishable goods.

7. **Ocean-going Vessels.** More than half the trade is carried on by steamers, but sailing vessels still carry the goods of large bulk and little cost (such as earthenware), where the time taken on a voyage is of little consequence : moreover, transport by sailing vessels is far cheaper than transport by steamship. The most important trade routes are :—

(*a*) **North Atlantic**—connecting ports on the north-west of Europe with ports on the north-east of America (Fig. 97).

Food-stuffs, timber, cotton, and tobacco cross from America, while textiles and metal goods return. The passenger traffic is also very great, most people going to America from Europe.

This route is short and needs no coaling station *en route.*

(*b*) **Suez Route.** This route serves the Mediterranean and Black Seas, the Indian Ocean, Australia, and the far East; and, as might be expected, the products carried are exceedingly varied.

It is a long route and possesses many coaling stations and naval stations.

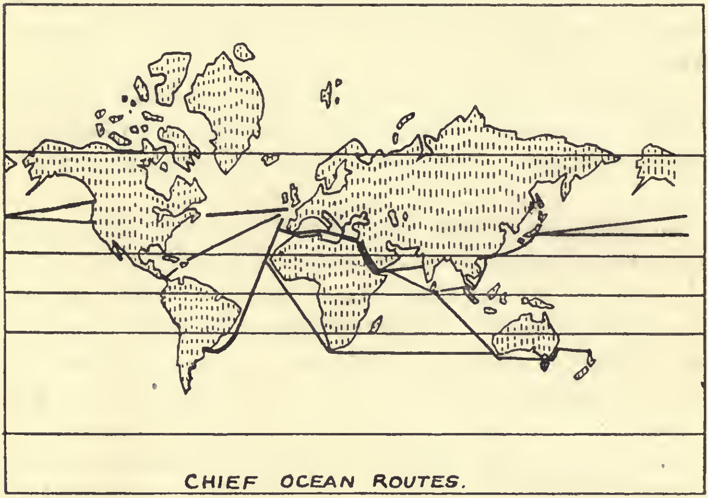

Fig. 97.

(*c*) **The Cape Route** is at the present time concerned chiefly with South African trade and a part of the Australian trade, but before the opening of the Suez Canal it was also on the way to India and South-east Asia. It also serves the West African regions. It is a fairly long route with several coaling stations.

(*d*) **The Plate Route** serves Brazil and the south-east of South America, bringing rubber and other tropical products from Brazil, and meat, wool, and grain from the Plate region.

(*e*) **The West Indian Route** serves the West Indies, Mexico, Central America, Colombia, Venezuela, and the

Guianas. On the completion of the Panama Canal this will be part of a route from the North Atlantic ports to the west coast of America, China and Japan, as well as an alternative route to Australasia.

8. **Railways** are superseding all other modes of transport on land, though peculiar conditions in scantily peopled regions, such as hot or cold deserts or very mountainous countries, will probably allow older forms of transport to continue for some time yet.

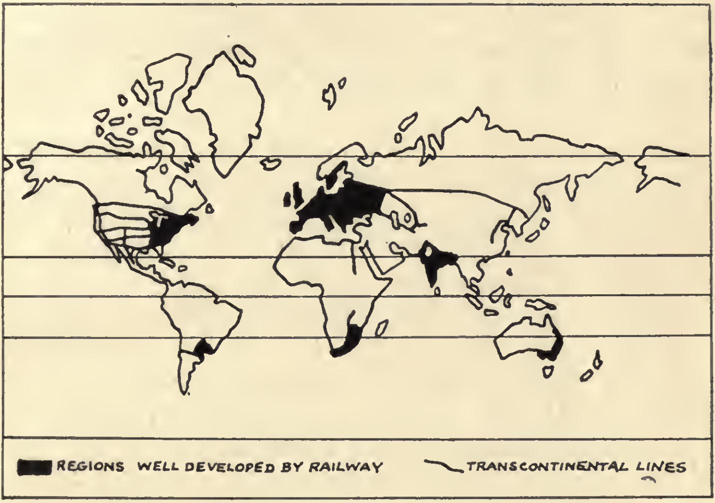

Fig. 98. Railways.

More or less level plains, which are densely peopled, are covered with a network of lines. These areas are connected by trunk lines, which form great trade routes (Fig. 98).

In hilly and mountain regions the railway lines of necessity follow the river valleys, and often in the same valley one finds several means of transport side by side. The Hudson-Mohawk is such a valley. First an Indian track, then a waggon road, next river and canal, and lastly a railroad carried produce across the Appalachians.

Railway freights are high compared with freights for transport by other means. But in some countries, as in Prussia, the government owns the railways and uses them as a convenience for manufacturers and consumers rather than as a source of profit, and consequently freights are lower than in countries where the lines are owned by private companies.

The development of the railways has called forth the use of the telegraph and telephone, and the improvement in our knowledge of electricity has given us telegraph cables and wireless telegraphy.

CHAPTER XXI

TOWNS

As we have already seen, towns first grew up in agricultural districts, and their use at first was to protect the agricultural population against invaders.

But such towns, being in more or less central positions, would naturally be convenient meeting places, and markets would be held there. The religious life of the community, as well as its government, would find the town its convenient centre.

Later on, towns would arise solely on account of trade, or religion, or government. At present trading towns are by far the most important, towns which are seats of governments or religious centres or fortified places being relatively few in number and small in size as a general rule.

Trading towns are places where all kinds of products are bought and sold, and such towns are a convenience both to the producer and to the consumer.

1. **Gates of Commerce.** This term is used to denote places where products enter and leave a country. The trade routes in the country converge on these places. Obviously they must be places on good harbours, but it must be noted that, unless backed by a productive region, the finest of harbours may be relatively useless. **Falmouth** and **Milford** are examples.

As rivers are often excellent trade routes, it is not to be wondered at that by far the greater number of gates of commerce are situated upon, or close to, the estuaries of navigable rivers.

Some harbours are shut off from the interior by a high range of mountains. This accounts for the scarcity of important gates of commerce upon the Pacific coast of America.

Seven out of the eleven towns having over a million inhabitants are situated on good harbours, reached by large vessels :—

London, New York, Canton, Tokio, Petrograd, Chicago, Philadelphia.

The following towns of over 500,000 inhabitants are situated upon or near estuaries :—

London, New York, Canton, Petrograd, Philadelphia, Calcutta, Tientsin, Buenos Ayres, Fuchow, Hamburg, Bangkok, Glasgow, Liverpool, Amsterdam, Marseilles, Baltimore.

Slightly smaller towns in similar situations are :—

Odessa, Shanghai, Alexandria, Lisbon, San Francisco, Bristol, Hull, Newcastle, Cardiff.

The following are upon good harbours, not shut off from the interior :—

Tokio, Constantinople, Bombay, Naples, Rio de

Janeiro, Osaka, Madras, Boston, Melbourne, Sydney, Copenhagen.

2. **Towns on Navigable Rivers.** Towns are often situated upon navigable rivers, especially where important tributaries join the main course, or where important roads cross the river. In very early times villages grew up at places where the rivers could be forded, and therefore where a road crossed the river, or where the river could be bridged. This accounts for the fact that many place names of villages and towns end in -ford.

The following are large towns on rivers :—

Paris, Berlin, Vienna, Moscow, Pekin, Calcutta, Tientsin, Hangkow, Warsaw, Cairo (Egypt), **Cairo** (U.S.A.).

3. **Intersection of Trade Routes.** Many of the above river-towns owe their importance, as well as their position, to the fact that other trade routes, roads, railways, or caravan routes converge on the river. But, as we have already seen, roads and railways run by the side of the river, so that a confluence is often a meeting place for river, road, and rail traffic.

In large plains, intersected by good rivers, roads, canals, and railways, the important commercial centre is often the geometric centre of the plain, so that a town of minor importance often outstrips the other towns. **Berlin** is probably the best example of such a town, but **Moscow** and **Birmingham** are other similar well-known towns. **Buda-Pesth** is in the centre of a fertile plain, and also upon an important waterway—the Danube.

Port Said is at the intersection of sea and land routes. **Constantinople** is another such town.

Some towns, like **Crewe** and **Swindon,** are railway creations, being situated at the junctions of important railway routes.

4. **Mining Towns.** Where valuable mines are opened

up, towns spring up in a surprisingly short time, even though the other surroundings are unfavourable. As long as the mines can be worked profitably, the towns flourish, but if the mines should cease to be profitable, the towns become deserted and the district may revert to a wilderness. On a small scale this may be seen even in the British Isles, as in certain tin-mining districts in Cornwall; but far better examples can be found in regions where the "rushes" have occurred. **Johannesburg, Kimberley, Koolgardie, Dawson City, Denver** are well-known mining towns.

5. **Manufacturing Towns.** At the present time, when most manufactures are carried on in factories, the factories are built in those places where power can be obtained most cheaply. The two principal sources of power are coal and falling water. Wood is used in some districts, and oil and natural gas are also employed.

(*a*) **Manufacturing Towns on Coalfields.** In the British Isles we have a large number of such towns. The particular industries carried on in each town will depend upon the peculiar conditions which obtain at the place.

(*b*) **Manufacturing Towns near Waterfalls.** The falling water is made to generate electricity, which can be put to many different uses. **Minneapolis** and **St Paul** on the Mississippi, and **Buffalo** near Niagara, are towns where such power is used.

6. **Fortified Towns.**

(*a*) **Fortified Towns on Land Frontiers.** These towns are situated along the natural roads and river valleys by which armies could cross the frontier. Thus the following French fortified towns are close to the frontier between France and Germany. **Belfort** guards the valley between the Vosges and Jura, **Epinal** and **Tour** guard the valley of the Moselle, and **Verdun** the valley of the Meuse. On the German side are **Metz** and **Strasburg.**

(*b*) **Fortified Towns on Coasts.** Some of these towns are arsenals, as **Portsmouth** and **Plymouth, Woolwich**, etc.

Others guard important trade routes, **Gibraltar, Malta, Aden, Quebec.**

Others are naval stations forming convenient bases for naval operations in different regions. Examples are **Dover, Halifax** (Nova Scotia), **Bermudas (Hamilton), Malta, Aden, Singapore, Hongkong, Esquimalt,** etc.

7. **Religious Centres.** Sometimes a town becomes the object of numerous pilgrimages on account of its religious associations, and the influx of people from different regions causes it to become a trading centre.

Mecca is perhaps the best example, but **Benares** and **Lhassa** are also good examples.

8. **Health Resorts.** In modern times, when travelling is no longer an arduous undertaking, and when the rate at which we live is a tax upon our nervous system, rest and change of scene become essential in order that we may retain our health. On this account a certain part of the year is devoted to holiday-making, when people leave the scenes of their labours and seek different surroundings. This has caused towns in certain districts to become very important. Of these health and pleasure resorts the most numerous are the seaside resorts. **Brighton, Scarborough, Ostend, Dieppe** are examples. Some inland districts are also frequented on account of the pure air and fine scenery. **The Lake District, Killarney, Loch Katrine, The Ardennes** in Belgium, **The Rhine Gorge, The Swiss Valleys** and **Mountains,** are examples of such inland resorts. **Switzerland** is a tourist resort throughout the year, its winter sports becoming more and more popular year by year, so that it well deserves its title of "The Playground of Europe."

Towns along the French and Italian Riviera are important health and pleasure resorts, especially in Spring.

Some towns owe their importance to the presence of medicinal springs, but they are usually made attractive to others besides invalids. Among such towns are the following:—**Spa** (Belgium), which gives its name to all such towns, **Harrogate, Buxton, Cheltenham, Bath, Marienbad, Homburg,** etc.

CHAPTER XXII

RACES OF MANKIND

Origin of the Human Race. It is practically a certainty that man evolved from anthropoid ape-like creatures, and it is usually thought that somewhere in South-east Asia is to be looked upon as the region where man—at least most of the types—originated. From this region mankind spread out over the earth. The present characteristics of people in any place are due principally to the following factors:—

1. The characteristics of the stock from which they migrated.

2. The geographical conditions obtaining in the place where they settled. This would cause variations to occur in the people, and these variations would in course of time cause the people to possess distinctive characters.

3. Later immigrations and intermarriages.

The superior intelligence of man has enabled him to overcome barriers which would be impassable to lower animals—especially climatic barriers, which he can cross because of artificial clothing and the use of fire.

It will easily be understood that the problem of the relationships of the various peoples on the earth is an exceedingly complex one, and especially so when we consider that the face of the earth itself has changed since man was evolved, so that, when man first spread over the earth, the distribution of land and water was very different from what it is at present.

Types of Man (Fig. 99). We shall give only a short list of the main types as they are found at present.

(i) **Black Type** or **Negro.** The following are the main characteristics of people of this type :—

(*a*) Black or dark brown skin. This is supposed to be due to the hot climate causing a greater supply of blood in the skin. This large supply causes the cells containing colouring matter to form the colouring matter in large amount. It is noteworthy that in all types the complexion darkens nearer and nearer the Equator. Even the whites of the eyes are "dirty."

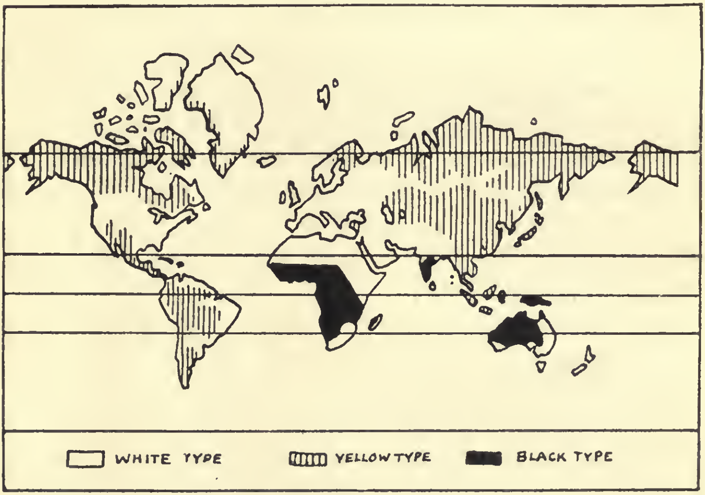

Fig. 99. Races of mankind.

(*b*) Curly black hair. The hair is flat in section, and hence it has a natural curl. Just as a round stick resists bending more than a flat one so a round hair is lank while a flat hair is curly.

(*c*) Broad nose.

(*d*) Thick lips.

(*e*) Protrudent jaws, receding forehead. The "facial angle" is smaller than with the other types. It indicates a lower degree of intelligence and a more brute-like nature than a large facial angle.

They are grouped as follows :—

(*a*) **African.**

1. **Soudanese**, between Sahara and Equatorial forests.

2. **Bantu**, between Equator and Kalahari Desert.

3. **Hottentots** and **Bushmen**, south of the Bantu.

4. **Negritos** and **Pygmies** of tropical forests ; these are the least intelligent of African negroes.

(*b*) **Oceanic.**

1. **Papuans** of New Guinea and adjacent islands.

2. **Melanesians** of Fiji and other islands.

3. **Australians** of Australia and Tasmania.

4. **Negritos**, a dwarfish people very similar to those of Africa.

(*c*) **American Negroes.**

American negroes are descendants of those formerly imported from Africa.

(ii) **Mongolic Type (Yellow).**

(*a*) Coarse straight hair round in section.

(*b*) Yellow skin. In the far north it is very pale, while in Equatorial regions it is brown.

(*c*) Nose medium in size but not shapely.

(*d*) Thick ill-formed lips.

(*e*) Eyeslit set obliquely.

(*f*) Features broad and flat, with high prominent cheek-bones.

They are grouped as follows :—

(*a*) **Northern (Sibiric).**

1. **Mongols**, nomads living on the steppes from the Caspian to the Behring Sea.

2. **Turks**, mainly nomadic and inhabiting Turkey, Asia Minor, and Turkestan.

3. **Finns** and **Lapps** in North Europe.

4. **Magyars** in Hungary.

5. **Siberians** in North-east Asia.

6. **Japanese.**

7. **Koreans.**

(*b*) **Southern (Sinitic).**

1. **Chinese.**

2. **Burmese** and **Siamese.**

3. **Tibetans.**

(*c*) **Oceanic.**

Malays are the most important in this division. They inhabit the islands of South-east Asia.

(iii) **American Type (Red Indian).** The American people have so many characters in common with the Mongolic people that there is little doubt that they are more nearly related to them than to any other type.

(*a*) Coarse straight black hair.

(*b*) Skin—the colour varies from yellow to copper and brown, the colour being darker in races living nearer the equator. The Amazonians are nearly black, the Red Indian is copper coloured, and the Alaskans are yellow.

(*c*) Nose is large, arched, narrow, and often well formed.

(*d*) Eyes are straight and of a jet black colour.

(*e*) The stature of the American is far greater than that of the Mongolic people.

Distribution :—

(*a*) **Northern.**

1. **Eskimo** in Alaska, North-west Territories and Labrador.

2. **Red Indian,** inhabiting the great plains of North America as far south as the Gulf of Mexico.

(*b*) **Central.**

Mexican is the principal group.

(*c*) **Southern.**

1. **Amazonians**, dwelling in the Amazon Basin. They are of a low grade of intelligence.

2. **South American Indians** (Gauchos and Patagonians), inhabiting the plains south of the Amazon Basin.

3. **Fuegians**, living in the extreme south. They are the most degraded of all American people.

(iv) **White Type** (**Caucasic**).

(*a*) Cranium well formed, especially in frontal region.

(*b*) Jaws are small and the facial angle is large.

(*c*) Eyes are set straight. The colour varies very much from blue to dark brown: usually blue eyes and fair hair go together while dark eyes are found in brunettes.

(*d*) Nose is large, well formed, narrow and straight.

(*e*) Lips are well formed, quite unlike the ugly and ill-formed lips of other types.

(*f*) Colour of the skin is variable. The skin is not absolutely devoid of colouring matter, but in some blonde people (Norwegians) it is practically nil. The skin, being relatively colourless, shows a tint due to the structures beneath. The pink colour is due to bright blood, while the blue tint is due to veins. In warmer countries the people may possess skins of an olive tint, or they may even be brown.

(*g*) Hair is oval in section, and, as it varies very greatly from nearly round to nearly flat, it is quite evident that there will be great differences in the amount of wave in the hair of different individuals, the hair of some being curly, while others will possess lank hair. The hair varies greatly in colour, being usually paler in people living in higher latitudes.

Distribution :—

(*a*) **Hamito-Semitic.**

1. **Hamitic**—these people settled in districts around the Mediterranean and in the British Isles. The following people belong to this group:—Egyptians, Somali, Basques, Picts, Silures, Ligures, Etruscans, and Pelasgi.

2. **Semitic**—Abyssinians, Arabs, Assyrians, Israelites, and Phoenicians.

(*b*) **Indo-European.**

1. **Hindu**—in the great plain of India.
2. **Dravida**—a degraded people in the Deccan.
3. **Iranian**—Persians, Afghans, Armenians.
4. **Greeks.**
5. **Celts**—Irish, Scotch, Manx, Welsh, Cornish, Breton.
6. **Italic**—Spanish, French, Italians, Roumanians.
7. **Slavonic**—Russians, Czechs, Poles, Bulgarians. Servians, Dalmatians, Montenegrins.
8. **Teutonic**—Scandinavians, Germans, Dutch, English.
9. **Caucasians.**
10. **Indonesians**—Maori, Samoan, Tahiti, Hawaii.
11. **Ainu**—Yezo, Kuriles, Sakalin.

CHAPTER XXIII

RELIGIONS

THERE is little doubt that by the time primitive man was sufficiently advanced to overrun the earth, he had some form of simple religion—crude ideas concerning life and death, and supernatural beings who controlled earthly affairs. His religion included ceremonies which were calculated to gain the favour or appease the wrath of these beings. Moreover, the religions of people so widely removed as the Mexicans (Aztecs) and Egyptians show such similarities that it is certain that many of the fundamental notions of all religions had arisen previous to the great migrations in the earliest times.

From these primitive notions the different religions were evolved.

The earliest gods are gods of the tribe, and it appears to be true of all tribes that their gods are dead men—dead priest-kings. In some tribes a priest-king or a substitute for him—sometimes a prisoner, sometimes an animal—was sacrificed every year. In Sir J. G. Frazer's *Golden Bough* there are very many instances of this manufacture of gods.

As the tribe advanced in civilization so the god was de-humanised, and still later the more advanced peoples attained to the conception of "one God." Some of these identified God with the universe—these are called **Pantheists.** Others conceived of a God outside the universe and controlling the changes in it, These are called **Monotheists.**

In early times "state and church"—community and worshippers—were united; in fact the king was priest, and, when he died or was sacrificed, he became a saint or minor god.

With a greater complexity in the life of the nation, priesthood and kingship became gradually severed. But for a great length of time scientific learning and priesthood were united. However, in modern times there is a greater and greater severance of the two, and in very few countries are Church and State even in nominal union.

For convenience religions may be classified as follows:—

1. **Heathenism** (Fig. 100). Under this heading are included the lowest types of religion, the worship of idols as the actual abodes of spirits, and the sacrifices of animals or even of human beings. This is often termed **Fetishism.**

Under the same term Heathen are included the **Polytheists** who believed in many gods. Some of these religions are of a low type while others, like that of the Greeks, have been held by highly civilized people and have inspired some of the most beautiful ideas ever given to the world.

2. **Monotheism.**

(*a*) **Pantheism** is a form of Monotheism, which identifies God with the universe.

(*b*) **Monotheism.** The believers in Monotheism hold that the universe was created and is sustained by one God. The chief divisions are :—

1. **Jews.**
2. **Christians—Roman, Greek, Protestant.**
3. **Mohammedans.**

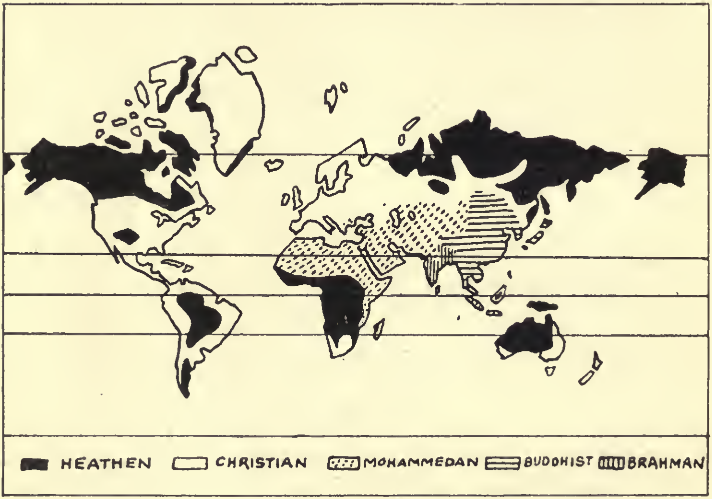

Fig. 100. Religions.

The above classification is not intended to be scientific, though it is probable that **Fetishism, Polytheism**, and **Monotheism** represent stages in the order in which the higher religions were evolved.

Moreover, it must be remembered that a very large number of adherents to the higher religions are only nominally so, and the tenets of their religion do not directly influence their lives. Some however, like Brahmins, are controlled more or less completely by their religion.

CHAPTER XXIV

GOVERNMENTS

As in the case of religions, very little will be said under the head of Governments, for not only is it a very wide subject, but it is highly controversial.

There is no doubt that in very early times, when man had not risen above the hunting stage of civilization, there was no government, for in the hunting stage a man's neighbours were his enemies. But as civilization advanced and man spread over the earth, individuals must often have banded together during raids or when fighting against the wild beasts, which to primitive man must have been terrible foes. This banding together would call forth a leader for the time being; and probably in this way the idea of obedience to authority originated. But hunters and nomads generally are, even at the present day, impatient of authority.

Pastoral people are more settled than hunters, but even they do not readily put up with oppression.

Agricultural people, crowded in fertile plains, need some form of regular government. At first, no doubt, custom was the rule of the life of the community. People in the agricultural state, and, in fact, in any settled state, are open to oppression either from outside robbers or from some of their own people who are able from various causes to control the lives and property of the ordinary mass of the people.

Consequently in agricultural regions it often happens that one finds a despotism, the despot governing according to his own will—nominally. But of course it is clear to anyone that no one man can govern a nation against the will of all the people. A despot must rule according to custom in very many ways, and he must always have upon his side either the greater part of the aristocracy (ruling classes), or the mass of the people (ruled), or a strong army (in which case the government is a military tyranny). Moreover, a benevolent despotism may appear to be a good thing for the people at times, though so long as the mass of the people take no hand in ruling themselves they cannot make very great progress. Enough has been said about despotism to show that the "label" put upon a form of government very rarely signifies the true type of that government. The same remark holds good with all other forms of government. Bearing this in mind, we may classify governments as follows :—

(i) **Despotism.** One person rules nominally according to his own will. He possesses full power over the life and property of every individual.

(ii) **Monarchies.**

(*a*) **Autocratic.** This form of government, which nominally differs little from a despotism, is usually an aristocracy—the "governing class" being the real rulers.

(*b*) **Limited.** This form of government is one in which the power of the king is limited by an assembly or parliament elected by the people.

In some limited monarchies the parliament possesses little power, and the king or emperor is more or less autocratic. Such a government is that of Germany.

In others the king has little or no power, except through ministers responsible to the people.

(iii) **Republic** or **Democracy.** In a republic all positions of power in the state are given directly or indirectly by election. The head of the state is usually termed a president. It will be seen that limited monarchies tend to approximate more and more to republican government.

A government where the moneyed classes can rule by reason of open corruption, or by the other means money has of obtaining power, is sometimes termed a **Plutocracy.** Any form of government, from despotisms to republics, may sometimes be termed a plutocracy by those who think that the moneyed classes are the real rulers.

Republics are sometimes divided into two groups—direct democracy and indirect democracy.

An indirect or representative democracy is one in which representatives, when elected for a term, have full power during their term of office. The people lose control, so to speak, of their representatives' actions until the next election. This gives rise to many abuses. The United States is an example.

A direct democracy is one in which the people do not lose control of the actions of their representatives. The people, if a certain specified proportion demand it, can initiate legislation, demand a referendum upon any measure, and recall any public official. The government of Switzerland is of this type, and, so far, appears to be the purest form of democratic government in the world.

INDEX

Aberration of Light 11
Aclinic line 50
Agonic line 50
Agriculture 194
Alluvium 161
Alpaca 124
Alpine Flora 103
Altitude and Temperature 58
Aluminium 186
Animals: Dispersal of 119
  Distribution of 118
  Domesticated 122
  Wild 126
Anthracite 187
Anticyclones 79, 95
Antitrades 77
Aries: Constellation of 23
Arrowroot 114
Ass 125, 197
Atmosphere: Composition of 52
  Depth of 52
Atmospheric Pressure and Altitude 71
  Distribution of 75
  January 82
  July 80
Australian Region 122
Autumn 23
Axis of the Earth 5, 15

Banana 114
Barley 110
Barometer 70
Barrier Reefs 135
Barriers to Migration 120
Base line 32
Beaches: Raised 168
Bise 84
Bluffs 158
Bora 84
Bores 143
Boulders 161
Brave West Winds 77

Calms 76, 77
Camel 124, 198
Campos 107
Canals 198
Cancer 17, 23
  Calms of 97
  Tropic of 25
Cañons 147
Caoutchouc 116
Capricorn 22, 24
  Calms of 97
  Tropic of 25
Carts and Waggons 198
Caverns in limestone 145
Celestial Poles 4, 5
Chalk 166
China clay 146
Chinook 84
Cinnamon 114
Circle: Antarctic 25
  Arctic 25
Clay 165, 180
  Limestones 181
Cloud 89
Cloves 115
Coal 186
  Bituminous 187
  Cannel 187
Coalfields: Industries on 188
Coasting Trade 199
Cocoa 113
Coffee 113
Col 38, 149
Compass 49
Condensation 87
Coniferae 117, 118
Constellations of the Zodiac 16
Continental Shelves 127, 168

Contours 34
Convection Currents 71
Copper 185
Coral 126, 134, 163
Co-tidal lines 140
Cotton 115
Crust of the Earth 26, 144
Currents in the Oceans 131
  in Inland Seas 134
Cyclones 79

Date 114
  Line 11
Day and Night 9
  Mean Solar 15
  Sidereal 14
  Solar 15
  Variation in length of 23
Deciduous Trees 118
Degrees: Subdivisions of 5
Delta 160
Deposits: Consolidation of 165
  Fluviatile 155
  Marine 161
Deserts 63, 102, 107, 120
Detritus in a valley 155
Dew 89
Dip 169
  Magnetic 50
Disintegration: Agents of 144
Dispersal of Species 119
Disturbances 80
Dog 123
Domesticated Animals 122
Downland 106
Duck 125
Dykes 176

Earth: Axis of 5
  Configuration of 27
  Crust of 26, 144
  Diameter of 3
  Minor inequalities of surface of 4
  Shape of 1
  Pillars 146
Elephant 125, 127
Embayment 36
Equator 5
Equatorial Belt of Climate 98
  Belt of Low Pressure 75
  Calms 76
Equinoxes 23
  Autumnal 24
  Vernal 23
Erosion 147
  Plane of Marine 168
Escarpment 170
Etesian Winds 84
Ethiopian Region 122
Evaporation 85

Faults 181
Ferrel's Law 11, 79
Fiords 168
Firn 152
Fish 126
Fishing 193
Flagstones 181
Flax 116
Flood Plain 157
Floor of the Sea 127
Fog 89
Föhn 84
Ford 156
Forests 104, 108
  Submerged 168
Fossils 163, 168
Foucault's Pendulum 10
Fowl 125
Fringing Reefs 134
Fur-bearing Animals 127

Gap 38, 174
Gas: Natural 187
Geysers 176
Ginger 115
Glaciers 152
Glens 148
Globigerina Ooze 130
Goat 124
Gold 186
Goose 125
Gorges 146, 174
Governments 215
Granite 177, 180
Grass Lands 105
Great Circles 5
Gregale 84
Grindstones 181

Habitat 118
Hachures 38
Haematite 185
Heat and Plant Life 101
Hemp 5
Hill-shading 38
Horizon 1
  Depression of 1
Horse 124, 198
  latitudes 97
Humidity of the Air 53
  Absolute 88

Humidity of the Air
  Relative 88
Hunting 192

Icebergs 153
Industries on Coalfields 188
Iron 184
  Manufacture 188
Ironstone: Clay 184
  Limestone 185
  Sandy 185
Isobars 71
  January 82
  July 80
Isoclinic Lines 50
Isogonic Lines 50
Isotherms 55
  January 65
  July 62

Jute 116

Karroo 106
Khamsin 84

Lakes 149
Land and Sea Breezes 72
Land and Water: Distribution of 29
Latitude 5
  Determination of 7
  Parallels of 6, 7
  Temperature and 56
Layer Colouring of Maps 38
Lead 185
Lemons 115
Levées 158
Libra: Constellation of 24
Lignite 187
Lime 181
Limestone 162, 180
  Carboniferous 166
  Oolitic 166
Llama 124, 198
Llanos 106
Loess 163
Longitude 8
  Determination of 12
  Time and 11
  Variation in length of one degree 9
Lowland Plains 128
Lumbering 195

Magnetic Declination 49
  Equator 50
  Inclination 50
  Meridian 49
Magnetic Declination
  Poles 52
Magnetite 185
Maize 111
Manufactures 196
Maps 32
  Atlas 34
  Cadastral 34
  Topographical 34
Marble 180
Mean Temperature 54, 58
Mediterranean Type of Climate 98
Mercury 186
Meridian 5, 10
Midsummer 17
Millet 111
Millstones 181
Minerals 144, 183
Mining 184, 195
Mist 89
Mistral 84
Moisture and Plant Life 100
Monsoons 83 98
Moon: Eclipse of 2
Moraines 149, 152
Mountain Flora 103
  Ranges 120
  Direction and Temperature 60
Mountains 178
  Importance of 179
Mud 161, 165
Mule 125, 197

Nearctic Region 121
Neotropical Region 122
Névé 152
New Zealand Region 122
Noon Position 9
Nutmeg 114

Oats 110
Occultation of Stars 12
Occupations 192
Oceanic Ridges 130
  Troughs 129
  Deposits in 129
Oceans 120
Oil: Mineral 187
  Shales 187
Olive Oil 115
Opium 115
Oranges 115
Ores 183
Oriental Region 122
Origin of Species 119
Outcrop 169

Ox 123
Oysters 126

Palaearctic Region 121
Pampas 106
Park Lands 107
Pass 38, 149
Pasturing 193
Peat 188
Pebbles 161
Pepper 114
Petroleum 187
Plants: Food of 99
Platinum 186
Pole Star: Daily Revolution of 3
Population: Density of 189
Porters 197
Potato 114
Pot holes 147
Prevailing Winds and Temperature 60
Projection 40
  Bonne's 45
  Globular 42
  Mercator 42
  Modified Globular 42
  Mollweide's 48
  Orthographic 40
  Sanson-Flamsteed's 46
  Simple Conical 43
  Stereographic 41
  Zenithal Equidistant 47
Proximity to the Sea and Temperature 60

Race: Tidal 143
Races of Mankind 207
Railways 201
Rain 145
Rainfall 90
  Highland Regions and 92
  in a Cyclone 94
  Mean Annual 91
  Mean Monthly 91
  Seasonal Distribution of 96
  Shadow 94
Range of Species 119
Reindeer 124
Religions 212
Revolution of Heavenly Bodies 4
Rice 111
River Gorges 174
  Terraces 159
Rivers 146
  Importance of 150
  Consequent 171
  Subsequent 173
Roaring Forties 77
Rocks 144
  Igneous 175
  Metamorphic 178
  Plutonic 177
  Sedimentary 165
Rotation of the Earth 10
Rubber 116
Rye 110

Saddle 36, 149
Sago 144
Salt 181
Sand 161
  Blown 163
Sandstone 166, 180
Savanna 107
Scale 33
Scarp 170
Sea 120, 154
Seal 126
Seasons 15
Sea Water 130
  Temperature of 131
Serpentine 180
Shale 166
Sheep 124
Shingle 161
Sidereal Day 14
Silkworm 125
Sill 176
Silver 186
Simoom 84
Sirocco 84
Skerries 150
Slates 166, 180
Slope and Temperature 56
Snowline 59
Solano 84
Solar Day 15
  Mean 15
Solstice 23
Spices 114
Sponges 126
Spring 23
Spur 36
Stalactite 163
Stalagmite 163
Steppes 106
Strait 120
Strike 169
Sugar Beet 113
  Cane 112
Sundial 13

Tapioca 114

Tea 113
Temperature: Annual Range of 67
  Circumstances affecting 56
  Daily Range of 55
  Mean Annual 55
  Mean Daily 55
  Mean Monthly 55
  of the Atmosphere 53
Thermometer: Continuous Curve 54
  Maximum 53
  Minimum 53
Tidal Bore 143
  Wave 138
Tides 135
  Neap 137
  Spring 137
Timber 117
Time; Greenwich 12
  Local 12
  Longitude and 11
Tin 185
Tobacco 116
Towns 202
Trade and Transport 196
  Routes 199
  Wind 77
  Wind Belts 98
Triangulation 33
Tropical Forests 108
  High Pressure Belts 76
  Trees 118
Tropics 24
Tundra 102
Types of Vegetation 102

Valleys 147
  Longitudinal and Transverse 170
Vegetable Productions 109
Vegetation and Temperature 61
Vicuña 124
Vine 112
Volcanoes 175, 176

Whales 126
Wheat 109
Winds and Pressure 71
Winter 22

Yak 198

Zenith 8
Zinc 186
Zodiac: Constellations of the 16
Zones 25
  of Vegetation and Altitude 101
Zoo-geographical Regions 121

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